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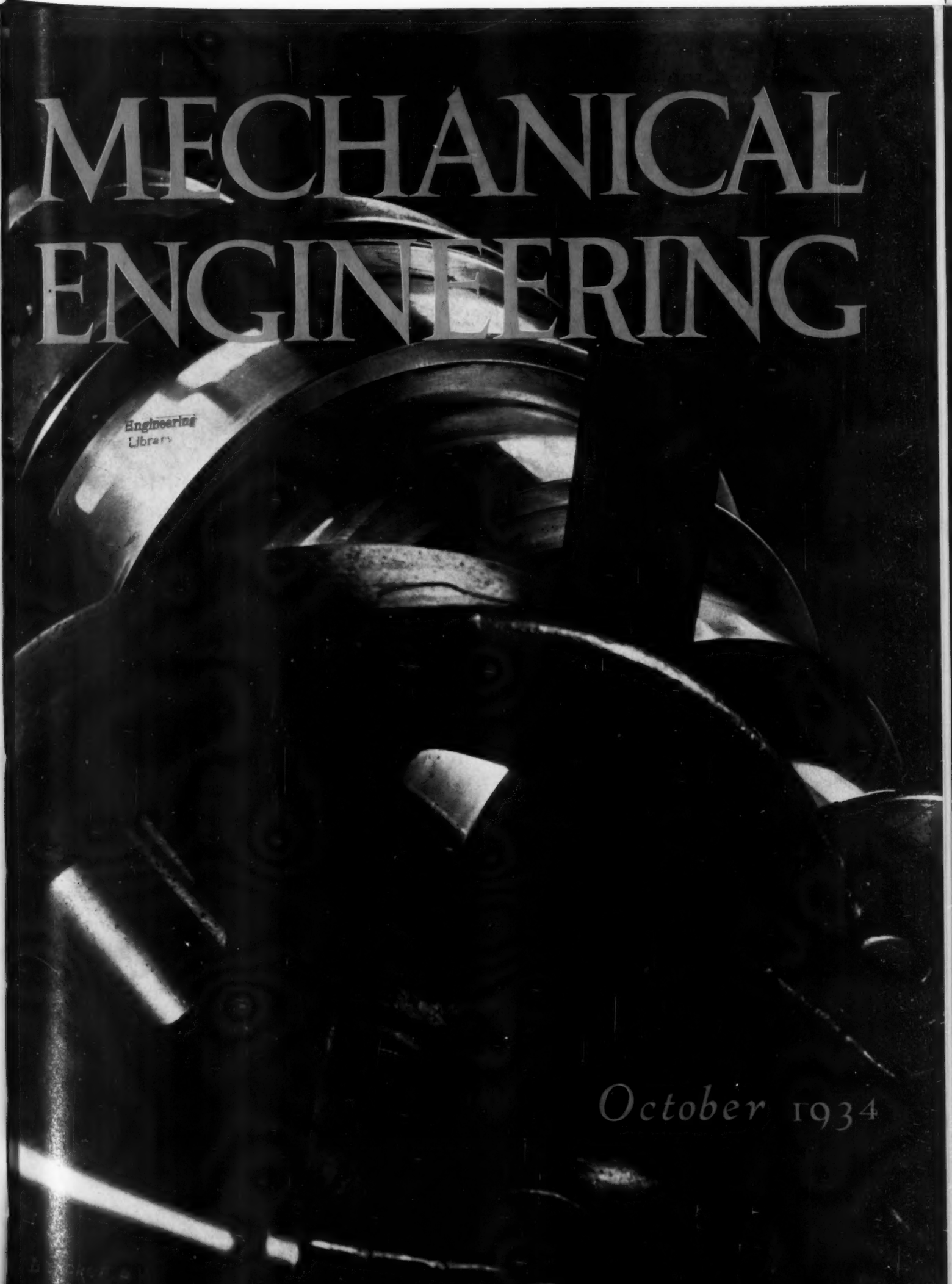

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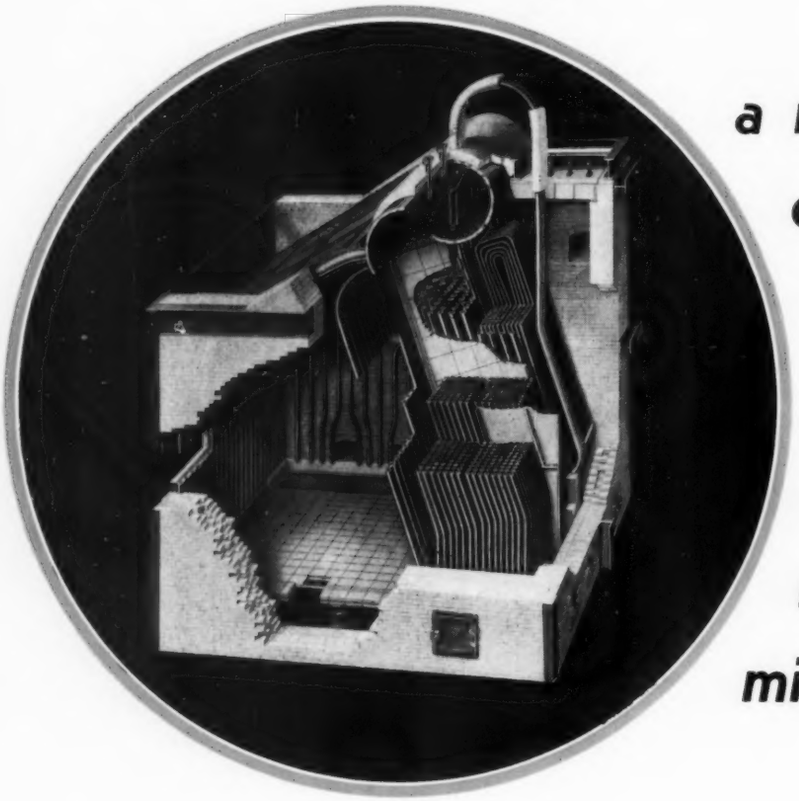

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MECHANICAL ENGINEERING

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Gerald Young

Carding Machine, Amana Woolen Mills, Iowa

(*See "Pictures" page 640*)

DURABLE GOODS *and* ENGINEERING EMPLOYMENT

A Report on the Present Situation, by the A.S.M.E. Committee on Capital Goods Industries[1]

ON JUNE 26, 1934, at the Semi-Annual Meeting of The American Society of Mechanical Engineers, in Denver, Colo., a resolution was adopted by the Local Sections Delegates and transmitted to the Council of the Society. This resolution has been referred to the Committee on Capital Goods Industries to frame a reply to be submitted to the Society.

The resolution, which is the occasion of this report, concerns the unemployment of engineers, the situation of the durable-goods industries, and measures for recovery and relief.

The resolution recites and suggests:

(1) Normally, engineers are employed largely in the durable-goods industries.

(2) Many engineers are now out of employment.

(3) The engineering profession should take positive steps to support the profession.

(4) The A.S.M.E. should take the initiative and request other societies to join with it to:

(*a*) Select projects of national, state, or civic benefit which must be performed by engineers;

(*b*) Bring these projects to the attention of the national government at Washington; and

(*c*) Point out the merits and benefits of the projects to the communities concerned.

(5) Work for a definite program with the united front of the large and influential membership of the A.S.M.E., in the hope and belief that a beneficial result may be obtained in Washington.

The matters treated in this resolution are of prime importance to members of the Society at this time. An attempt will be made, therefore, to deal with the issues raised, and the situations presented, as well as the violently shifting conditions permit.

ENGINEERING EMPLOYMENT

Engineers have suffered desperately because of unemployment. Estimates of the number out of work have ranged up to 50 per cent of all engineers in the United States.

The past year has shown improvement, although dependable quantitative records are lacking. Indications of the trend are shown by the figures on placements of the Engineering Societies Employment Service. The combined averages for the New York, Chicago, and San Francisco offices are: Placements for 1932, average per month, 50; placements for 1933, average per month, 72; placements for six months of 1934, average per month, 75. While the direction of this trend is favorable, the quantitative results are pitiably inadequate when measured against the need.

As to the future of engineering employment there are most optimistic predictions. Gen. R. I. Rees, vice-president of the American Telephone and Telegraph Company, reports from a statistical study made by his staff that from 1927 to 1933 the number of engineering graduations in the United States was probably somewhat in excess of the trend curve of demand, but the tide has undoubtedly turned, and from 1933 to 1937 there will be a marked deficiency of engineering graduates as compared with normal requirements.

Dr. Harvey N. Davis, writing in the *Stevens Indicator* for May, 1934, gives this specific forecast "……by 1938, perhaps even by 1936, industry will be facing the worst shortage of technically trained men it has ever known, and this for all classes and levels of technical ability from coppersmiths, sheet-metal workers, machinists, and steam-shovel operators to research men with doctors' degrees."

In this connection the fact must not be overlooked that certain permanent changes have taken place and are in progress in business and industry. The searcher for an engineering position will be well advised to appraise his capabilities in terms of the functions he can perform, not by a list of the jobs he has held or would like to hold.

THE DURABLE-GOODS INDUSTRIES

Employment and unemployment in the durable-goods industries has not changed substantially during the months of 1934. In March of this year, Col. Leonard P. Ayres estimated that the unemployed in all durable-goods industries in the United States was 2,027,000 in the construction industries, and 2,709,000 in other durable-goods industries, a total of 4,736,000.

The unemployed in all groups providing services and producing goods was 9,357,000. Thus somewhat over one-half of the unemployed are in groups whose normal employment is in the durable-goods industries. The

[1] A progress report of the A.S.M.E. Capital Goods Industries Committee was published in the February, 1934, issue of MECHANICAL ENGINEERING, pp. 85–86. The committee, appointed by the Council of The American Society of Mechanical Engineers, in September, 1933, consists of the following: L. P. Alford, *Chairman*, Ralph E. Flanders, W. W. Macon, and L. W. W. Morrow. The present report will be submitted to Council on Sept. 19, 1934.

principal cause for this situation is given in the report of the Durable-Goods Industries Committee,[2] as follows:

"Durable goods are produced more rapidly through the incurment of debt than savings are accumulated during the optimistic period of an upturn in the economic cycle, with a corresponding expansion of credit; while during the pessimistic downturn in an economic cycle, durable goods are purchased at a lesser rate than savings are accumulated, resulting in the payment of debt and the contraction of credit. It is axiomatic that debt is incurred during good times and liquidated during hard times and that an excess of debt accumulation is an important contribution to the causes leading to the termination of such periods of prosperity. This cycle of events applies almost exclusively to the demand for durable goods and is not found to anything like the same degree in the field of consumptive goods. It is this characteristic that causes the great fluctuation in employment in the durable-goods field, and has largely caused the present stagnation in these industries."

The preceding disclosures set out the problem of business recovery as:

(1) The greater mass of unemployment is in the durable-goods industries, particularly in the construction groups.

(2) The durable-goods industries cannot absorb more workers until their sales volume increases.

(3) No substantial increase in the sales volume of the durable-goods industries can be expected until public confidence is restored and private individuals begin to use their resources of capital and credit in new undertakings.

Chief among the fundamental conditions needed for recovery, according to the Durable-Goods Industries Committee, which we quote with approval, are:

(1) A free flow of private capital into private business.

(2) A sound real-estate mortgage market.

(3) Industrial relations on a basis which will assure cooperation instead of strife.

(4) A balanced price parity between agricultural commodities and manufactured goods.

(5) The further reestablishment of confidence—most important of all.

While awaiting the coming of recovery, the outstanding opportunities for stimulating reemployment are in modernizing existing construction and erecting new construction. The report of the Durable-Goods Industries Committee indicates the following items in a national program: Home modernizing, business-building modernizing, modernizing factory and power-plant equipment, modernizing public works and equipment, farm-equipment replacement, rehabilitating railways, new construction, new home-building, furnishings, slum clearance, reforestation, highways, railway crossings, water and sewer systems, water filtration, steam clearance, and purification, sewage-disposal plants and incinerators, rural electrification, airports, and parks and recreational facilities.

It is evident that such a program demands the united support of Federal, state, and local government, national, state, and local civic organizations, and banks, business houses, and financial institutions. The molding and directing of public opinion is an imperative requirement to the success of such an undertaking.

To show what the Federal Government has done and plans to do to stimulate construction and modernization, it is necessary to review the allotments made by the Federal Emergency Administration of Public Works and the plans being put into effect under the National Housing Act.

PUBLIC-WORKS ADMINISTRATION

The allotments of the Public Works Administration up to August 1, 1934, totaled nearly $3,700,000,000. These allotments are classified as follows:

Federal allotments	$1,527,030,517
Legislative and executive allotments	1,167,725,666
Non-Federal allotments	975,615,921
Total	$3,670,372,104

The Federal allotments are to the various departments and independent offices of the Government and the District of Columbia.

Departments	
Agriculture	$ 457,035,062
Commerce	15,454,800
Interior	219,797,648
Justice	785,512
Labor	2,758,980
Post Office	532,600
State	5,757,318
Navy	277,098,924
Treasury	97,171,288
War	439,672,964
Independent offices	9,205,921
District of Columbia	1,759,500
	$1,527,030,517

Not all of these sums are ear-marked for construction or equipment. Certain administrative, research, and other items have been included. The smallness of the allocation to the Post Office Department may seem surprising, until the fact is recalled that the Treasury Department constructs the post-office buildings. In all, 406 new post-office structures are projected.

The legislative and executive allotments include numerous items that are not for construction or equipment. The emergency conservation work and Civil Works Administration together are assigned $723,367,315 of the total in this classification.

[2] See "Report to the President of the United States on National Recovery and Employment," by the Durable-Goods Industries Committee, May 14, 1934, p. 11. The Durable-Goods Industries Committee was elected by the Code Authorities at the close of the Conference of Code Authorities in Washington, March 8.

The construction projects making up the non-federal allotments include 3834 of various kinds, 43 to railroads, and 10 for low-cost housing. The main classification includes 3580 buildings, 1170 for streets and highways, 387 aids to navigation, 237 structures (bridges, docks, tunnels, and others), 200 for reclamation and flood control, 141 for the construction of vessels. To show the variety of these projects in some detail, page 1 of Release No. 900 of the Federal Emergency Administration of Public Works lists these different items of construction: abattoirs, bridges, courthouses, curbs, dams, disposal plants, dormitories, drainage, electric plants, gymnasiums, heat and power, high-schools, highways, hospitals, irrigation, libraries, schools, stadiums, streets, town halls, water mains, water tanks, water works, and well pumps.

It is difficult to separate out the construction items with certainty from those that make up the allotments of $3,700,000,000. However, it appears that some $2,700,000,000 of the total falls into this classification. As of August 1, about 0.2 per cent of the total allotments were to projects that had been completed. Construction under way accounts for about 50 per cent. It is estimated that the work to be done will be spread over some three years. This gives an average annual expenditure of $900,000,000.

While this is a huge sum from the viewpoint of taxation, it is a pitiably small sum when compared with the amount spent in national construction in years of prosperity. The relation is shown in the following tabulation:

Average, annual, national construction (1925–1929)	$10,900,000,000
National construction, 1933	3,100,000,000
Average, annual PWA construction (Aug. 1, 1934, to Aug. 1, 1937)	900,000,000

These comparisons show, on the one hand, how imperative is the restoration of business confidence, and, on the other, how meager is the total of public-works construction when measured against the employment need. During 1925–1929, 75 per cent of construction was by private concerns and utility companies. The corresponding figure for 1933 is 60 per cent.

FEDERAL HOUSING ADMINISTRATION

A Federal Housing Administration has been created under the National Housing Act which became law June 27, 1934. Under this authority it is expected that aid will be given to break the credit jam that has been holding back work.

It is estimated that 16,000,000 buildings in the United States have reached a more or less serious state of disrepair. Of these 3,000,000 have deteriorated to a physical state where a major building operation is necessary to save them. The repair of many is economically unjustified, and they should be demolished. For the national good it is essential that repair and reconditioning be begun at once.

The Federal Housing Administration proposes to stimulate the flow of private capital into three kinds of building and construction work:

(1) *Renovation and Modernization of Real Property.* The plan is to stimulate alterations, repairs, and improvements upon real property by providing an instalment-payment plan to be executed through established lending institutions with the Federal Government, guaranteeing each participating institution against losses up to 20 per cent of the total loans for these purposes, which it makes.

(2) *Construction of Houses to Be Occupied by Owners.* The plan is to stimulate the construction of owner-occupied homes, when and where needed, by providing the borrower with a single amortized mortgage up to 80 per cent of the appraised value of the property, at an interest rate not to exceed 5 per cent (or not to exceed 6 per cent if the Housing Administrator finds that the mortgage market demands it), and the lender with a mutually insured mortgage.

(3) *Construction of Residential Rental Properties for Persons With Low Incomes.* The plan is to stimulate the construction of housing to be rented to persons with low incomes by insuring mortgages on such properties held by agencies which are subject to regulation by law or by the Housing Administrator as to rents they charge, capital structures, rates of return, and other methods of operation, that is, private, limited-dividend corporations, and Federal, state, or local housing authorities.

These mortgages will be placed in a single fund. They have no limitation as to percentage of coverage of appraised value. Insurance with respect to any one such housing project may not exceed $10,000,000.

For the first plan a guarantee fund of $200,000,000 is provided. For the second and third plans a revolving fund is created. The original allocation is $10,000,000. The total amount of insurance on existing homes is limited to $1,000,000,000. The total amount of insurance on new homes, including low-cost-housing rental projects, is limited to $1,000,000,000.

Fears have already been expressed as to the extent and success of these national housing plans. Two views are urged to support these fears. Home owners, who are in none too favorable a financial situation after five years of depression, will be loathe to go into debt for renovating and modernization. Banks, which are still suffering from experiences brought on by depression, will tend to withhold funds despite the Federal 20 per cent guarantee on housing loans. The amount of employment resulting from the construction and modernization under these national plans for housing will be in proportion to the degree these fears and hesitations are overcome.

NATIONAL RECOVERY ADMINISTRATION

The charge is made that the limitations and restrictions on size of equipment and output of production are a deterring factor in the purchase and installation of new manufacturing equipment. It is true that many of these codes have such restricting provisions. The A.S.M.E.

Capital Goods Industries Committee plans to report fully on this matter as soon as a study that is now under way is completed.

Doubt can be expressed as to the importance of these provisions as a restraining influence. During the first two quarters of 1934, the automotive industry was active. However, it bought almost no new machine tools, a situation in sharp contrast with its record during all preceding periods of good business.

THE SECURITIES ACT

The Durable Goods Industries Committee early in the year expressed this opinion: "....industry is convinced that the Securities Act of 1933, which was intended to protect the investor by regulating the issuance and sale of securities, actually has had the effect of preventing the issuance of such securities." Opposed to this opinion is the fact that from July, 1933, to July 31, 1934, there were 750 issues registered, amounting to $1,070,-237,539.63. Business has discovered that the act is not the hampering influence that was feared.

Two other facts have a bearing on the availability of funds for construction and equipment. The assay[3] made by the A.S.M.E. Capital Goods Industries Committee early in 1934 indicated that many industrial concerns had ample funds for extension and replacements, but were unwilling to extend or replace because of lack of confidence.

LOANS TO INDUSTRIAL CONCERNS

For industrial and commercial concerns whose resources have been more or less depleted, loans are obtainable from both the Reconstruction Finance Corporation and the Federal Reserve banking system. As yet not much has been borrowed from either agency by industrial companies, but for that matter, the opportunity has not long existed, even in the case of the RFC.

The Federal Reserve act was amended to fill the need for intermediate credits. Companies requiring funds to help finance, say, the execution of a construction or equipment contract, may borrow for working-capital account on terms that allow five years for final payment. A feature of the financing procedure is dependence on industrial advisory committees. A given bank or lending institution (which may have the backing of the Federal Reserve Bank up to 80 per cent of the amount of the proposed loan) or the district Reserve bank itself makes the loans on the recommendation of the industrial committees. Each of these, one for each of the twelve reserve districts, is composed of five active industrial or business men, of high reputation in the community, who serve without compensation.

PUBLIC CONFIDENCE

In preceding paragraphs the opinion has been stated, or implied, that confidence is the most important requisite to recovery. This view cannot have overemphasis. The very foundation of our national recovery is business confidence. The elimination of unemployment will come from the free flow of capital into private business and industry. This movement of funds will occur when investors believe that nothing in the national situation will endanger the safety of their investments and the opportunity to earn a fair profit.

SIX ESSENTIALS FOR CONFIDENCE

The Durable-Goods Industries Committee lists six essentials to the establishing of confidence:

(1) Assurance to private enterprise that the profit incentive will continue to receive public approval as an energizing motive for economic activity.

(2) Public recognition that the only legitimate purpose of taxation is to provide the necessary revenue for government and not to effect a punitive redistribution of wealth, which paralyzes business initiative, or for any other purpose.

(3) Removal through a permanent balancing of the budget of the threat of uncontrolled inflation.

(4) Removal of any remaining threat of a sudden and arbitrary change in our monetary policies.

(5) Assurance that companies which have adjusted their business methods and policies to the temporary emergency program of the NRA will be free from the uncertainties of unreasonable or arbitrary administrations.

(6) Clarification of the Government's policies toward measures and trends which are inconsistent with our economic system.

RECOMMENDATIONS

The resolution of the A.S.M.E. Local Sections Delegates which provided the occasion for preparing this review of the work of certain agencies and movements having to do with construction and modernization, deals primarily with the problem of unemployment among engineers. It asks for a definite program. These recommendations are offered:

(1) That the Council review the methods now in force in the Engineering Societies Employment Service to make sure that full information in regard to all opportunities for engineering employment reaches promptly all the members of the Society.

(2) That the Council arrange for the immediate transmission of information in regard to all Federal opportunities for engineering employment and engineering work to the members of the Society. The source of this information might properly be the Washington office of the American Engineering Council.

(3) That the Council conduct a program of publicity through the local sections of the Society to reach as many local newspapers as possible to stimulate the initiation of local construction or modernization projects requiring engineers and engineering work.

(4) That the Council assist constructively, in every proper way, in the upbuilding of public confidence, the imperative essential to business recovery.

[3] See MECHANICAL ENGINEERING, February, 1934, pp. 85–86.

The ECONOMICS *of* PURCHASING

A Review of Some Fundamental Principles to Be Observed in Purchasing

By WALTER RAUTENSTRAUCH[1]

THE PROBLEM of purchasing assumes varying degrees of importance in industry according to the influence which the material or equipment purchased has on the costs of the business. In industries in which material costs are relatively great, as in meat packing, fertilizer manufacture, and the building of electrical transformers, the price per unit of material is a highly important factor. In industries in which the cost of converting the raw materials into salable products is relatively high, the purchase of the equipment or machinery of manufacture and the supply materials of production, which influence the costs of manufacture, assume an important place. The purchaser of materials and machines is an investor of funds charged with the responsibility of making the best possible investment in the materials and machines which the management prescribes shall be procured.

Purchasing is the act of converting money or credit into goods and services. A purchase is said to be good when the "value" of the materials and machines is a maximum, while the price is a minimum. The economics of purchasing, therefore, is concerned with estimating the probability of "value" of the goods offered in relation to price.

The setting of the purchasing problem in the whole economic cycle of value changes in industry is illustrated in Fig. 1.

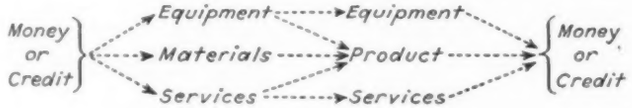

FIG. 1

Business enterprises which involve manufacture have three principal economic problems. The first is to convert money or credit into equipment, materials, and services. The second is the flow and assembly of the values of equipment, materials, and services into salable goods or products. The third is to convert the products back into money or credit by merchandizing.

The economic cycle in industry, which Fig. 1 illustrates, consists of three phases, each of which has a bearing on the problem of purchasing. The first phase relates directly to the act of purchasing by which money or credit is converted into:

(1) Equipment, e.g., land, buildings, and machines.
(2) Materials, i.e., direct materials becoming part of the product, and supplies used in production and trade, or indirect materials.
(3) Services, that is, management, labor, insurance and taxes, and power, transportation, communication, heat, light, etc.

The second phase relates to the utilization of equipment, material, and services in the creation of a product. The efficiency of this phase of the economic cycle is determined by the factory management, operating within the limits prescribed by the equipment and materials used.

The third phase is the act of merchandizing by which the products are converted into money or credit.

The purchasing function has a bearing on the second and third phases of the economic cycle in that it affects the costs of manufacture and the quality of the product. Suitable equipment and material tend to lower the cost of production and therefore tend to increase the spread between selling price and cost of manufacture. The quality of the product tends to reduce sales resistance and to lower servicing costs, and thus contributes to the reduction of merchandizing costs.

THE PURCHASE OF EQUIPMENT

The value of a machine or piece of manufacturing equipment may be judged by its influence on the cost per unit of output at varying rates of production. The factors which determine the costs are:

The cost to procure, P

(1) Purchase price
(2) Transportation charges
(3) Placement costs

The cost to possess, A

(1) Interest at a per cent $= Pa$
(2) Taxes at b per cent $= Pb$
(3) Insurance at c per cent $= Pc$

The cost to operate, O

(1) Labor
(2) Services

The cost to replace, D

(1) Depreciation at d per cent $= Pd$

Let P = the cost to procure, dollars
A = the annual cost to possess, dollars per year
$= P(a + b + c)$
O = the cost to operate per hour, dollars per hour
= labor cost per hour + service cost per hour
$= l + s$, dollars per hour
D = annual depreciation
$= Pd$, dollars per year
N = estimated annual output, number per year
n = estimated hourly output, number per hour
t = cost per unit of output, dollars per unit.

Thus
$$t = \frac{A + D}{N} + \frac{O}{n}$$
$$= \frac{P(a + b + c + d)}{N} + \frac{l + s}{n}$$

The usefulness of this formula depends on the accuracy with which the values of the factors are predicted. The value of a machine process compared to hand labor in terms of cost per

[1] Professor of Industrial Engineering, Columbia University, New York, N. Y. Mem. A.S.M.E.

Presented at a meeting of the Management Division, Metropolitan Section, New York, N. Y., May 2, 1934, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

unit of output t at varying rates of production N is shown in Fig. 2.

When production is at a rate between 0 and x_1, the hand process is more economical than the machine process. The purchase of the machine is justified for rates of production from x_1 to x_2 provided the rate continues for a sufficient time period.

The comparative value of competitive equipment in terms of the cost per unit of product at varying rates of production is shown in Fig. 3.

Machine A is the more advantageous purchase when the annual production is within the range 0 to x_1, while machine B is indicated for rates of production from x_1 to x_2.

Since one of the problems of management is to make the best investment of available funds, it may be more advantageous

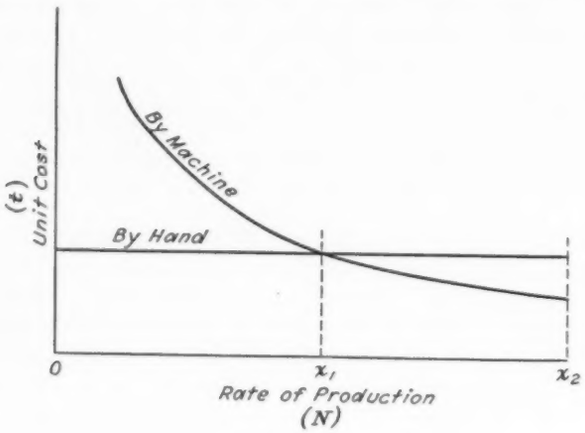

FIG. 2

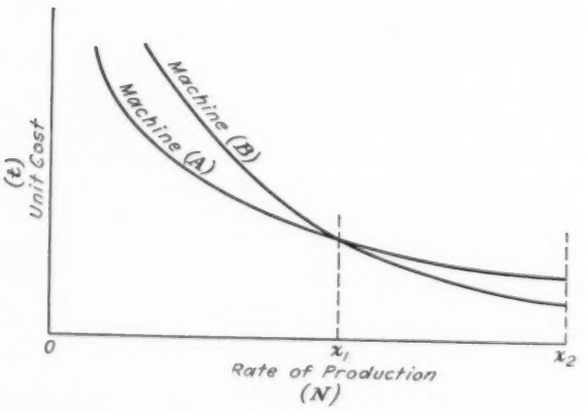

FIG. 3

to a business not to replace machine A by machine B when the same sum invested in new power equipment, for example, may pay a greater return.

THE PURCHASE OF MATERIALS AND PARTS

Materials which are to become part of the product should be purchased with reference to: (1) their adaptability to intended use, (2) the cost of processing, including waste, and (3) the purchase price.

The conduct of a business involving manufacturing operations does not require that all parts should be fabricated in the company's own plant. Indeed, it is always a question with a manufacturer as to which parts to manufacture in his own plant and which to purchase from others. Since the object is to place products on the market at the lowest cost and thus obtain the widest spread between the cost and the selling price, it follows that the parts of which the product is made should be obtained at the lowest cost, whether in one's own plant or elsewhere. This problem is also important because its solution will determine the amounts of fixed capital and working capital to be provided, as well as the types of organization for manufacturing and for servicing.

The considerations which should guide one in this matter are as follows:

(1) What is the relative return on the investment to provide for the manufacture of certain parts as compared to purchasing them ready for assembly or even in a semi-finished state?

(2) Is the supply of the parts which may be purchased adequate to insure regularity and the maintenance of low prices in competitive bidding?

(3) Shall certain parts which are patented but which can be purchased from other manufacturers be used, or is there a danger in their use because of the question of patent validity?

(4) Of parts which may be purchased from any of several manufacturers, which has the greatest public acceptance?

(5) If a given part is purchased from another manufacturer, what servicing can and does this manufacturer provide to the users of these units?

(6) Is the quantity of any part of the product to be manufactured too small to justify the investment in special machinery required to produce it, and would it be advisable to purchase these parts from others better equipped for this work?

(7) Shall a complete line of sizes and styles (valves, for example) be manufactured or shall the business be devoted to manufacturing a few styles and sizes?

All of these questions have a direct bearing on what manufacturing facilities shall be provided and on the capital requirements of the business. The products should be carefully examined with respect to these particulars before any steps are taken to provide manufacturing facilities.

The four important considerations which govern the adequacy of a given source of supply of parts are: (1) continuous delivery, (2) prompt delivery, (3) fair price, and (4) elasticity to meet emergency requirements.

One of the objectives to be accomplished in the operation of a factory is the quickest turn-over of working capital. One of the factors in rapidity of capital turn-over is the time between arrival of materials and their being put in process. If materials are put in process immediately upon arrival, conditions are ideal. If material is stored several weeks or months before being put in process, its value represents so much idle capital. If material arrives after it has been scheduled to be put in process, machinery, as well as other material with which it is to be assembled, is idle, with resulting increase to costs. These probabilities must be weighed against price. Economy does not always reside in low first cost. Accordingly, it may be better to manufacture certain parts in one's own plant even though they may be purchased at a lower price from others, to insure against delays in the assembly line. Sometimes one must consider the possibility of taking on a large order and working the shop overtime. This cannot be done if the supplier of a certain part cannot also meet this increased schedule of requirements. No general rules can be laid down for the determination of the adequacy of the source of supply of contemplated purchased parts, but the four considerations enumerated must be taken into account in arriving at a sound judgment.

In contemplating the manufacture of completely assembled units for use in the principal products, such, for example, as

magnetos for tractors and motors for washing machines, one must consider also the cost of maintaining specialists in the design of such parts of the principal products. The overhead due to providing the skill necessary to design and produce a unit of this nature and to adapt it to new requirements is sometimes large. Furthermore, when a manufacturer is equipped to produce these specialty units, he cannot take advantage of improvements which may be made by specialty manufacturers. Take the case of the magneto, for illustration. If the tractor manufacturer equips his plant for the manufacture of his own magnetos and a specialist in magneto manufacture brings out a greatly superior product at lower cost, the manufacturer is not free to adopt this unit because of his investment in equipment and organization for the manufacture of his own product. It may pay him to reverse his policy, dispose of his equipment, and adopt the new magneto. With the constant changes being made as a result of research and new developments, the manufacturer who produces his own parts or units which are used in a rapidly developing art always runs the risk of having his equipment become obsolete unless he produces a sufficient quantity to maintain a development laboratory and keep up with the times.

The same general principle applies to parts demanding special skill to produce. It often pays to purchase parts requiring special skills and to concentrate on the manufacture of parts belonging to a given class of skills or requiring the use of certain types of equipment only. Cost of production in general rises with the multiplication of the arts and skills which have to be employed in the factory. This is particularly true in the case of small-quantity production, which cannot carry the overhead necessary to the proper organization and management of a variety of industrial processes.

The problems which arise in determining the parts of the product to be manufactured cannot be solved by means of formulas. The factors to be coordinated are too varied and complex to admit of a formulated solution. One can only suggest the matters which should be inquired into and the general principles which should be recognized in the solution of this problem.

THE PURCHASE OF SUPPLIES

Supplies, such as oil, sandpaper, files, crucibles, packing, and hundreds of similar materials, are frequently purchased without consideration of the real factors involved. When one contemplates the fact that these materials are purchased solely for what can be accomplished by their use, the real problem involved in their purchase is indicated. When coal is measured on the basis of heat units instead of weight, the correct basis of purchase is established. But the same purchaser who buys coal on the basis of heat units will purchase stuffing-box packing by the pound, lubricating oils by the gallon, files by style and quantity, and cutting compounds by the barrel. This is largely because there are no units, methods, and means of measurement of the real elements of the purchase. The establishment of a correct basis for the purchase of supplies should be considered by associations of purchasing agents working in cooperation with associations of manufacturers.

Supplies such as files, sand-paper, hack-saw blades, and lubricating oils, to mention only a few, are used in manufacture to serve a purpose; and *the cost per unit of service* is the correct basis on which to judge the price offerings of the sellers of supplies.

The first problem in evaluating the worth of a supply material is to determine the unit of service. This of course will be expressed in different terms for each kind of material.

The next problem is to formulate a method by which the amount of service may be measured.

The final problem is to design a means embodying the method. A report illustrating this type of procedure will be found in *Manufacturing Industries*, September, 1928, by Commander Timothy J. Keleher and Frank M. McGeary, materials engineers, both of the United States Navy. Their report on hack-saw blades is a good example. The unit of service established was the ratio of the number of cuts to the number of strokes per cut of a 3-in. round bar of specified analysis. A few tests indicated that 0.00025 was a suitable dimension for this unit. The method of test was to have each blade operate under the same load and travel at the same speed in cutting. This was embodied in a standard hack-saw cutting machine. The results of a number of tests gave values in terms of ten-thousandths of 37.7, 29.5, 25.5, 18.8, and 14.1. Since the price of the best blade was only 10 per cent higher than that of the worst blade, these two blades compared as 34.3 to 14.1. The cost per unit of service thus varied 244 per cent.

Standardization and simplification are also factors of considerable importance in the economics of the purchasing of both materials and supplies. The general problem of purchasing is quite similar to that of horse-trading. The best trader is the one who knows most about the horse. A technical training is therefore a good background for those horse-traders who deal in the purchase of those particular brands of horses known as materials and equipment.

Clarence E. Weinland

INCREMENT COSTS *and* SUNK COSTS

With Examples of Some of the Confusion That Results From a Misunderstanding of Them

By EUGENE L. GRANT[1]

THERE is much evidence that incorrect reasoning is fairly common where decisions on matters of engineering economy involve increment costs and sunk costs. Such evidence may be found in engineering reports and in technical books, articles, and formulas dealing with matters of economy.

In order to understand the nature of these common errors it is helpful to consider some characteristics of decisions in general. Whenever any one makes a decision as to what to do it is necessarily a choice between alternatives, and these alternatives necessarily relate to the future. Perhaps the majority of every-day decisions which we make are based on intuitive judgments or "hunches" without any conscious attempt either to define exactly what the alternatives are or to predict their effect. But on matters of engineering economy an attempt is usually made to choose between definite alternatives on the basis of the best forecasts of costs (and revenues) which it is possible to make.

In considering these decisions in which conscious forecasts of costs are made, it is convenient to discuss them as if they always involved only two possible alternatives. In practise there may be many more, but successive eliminations may always be made by consideration of pairs.

INCREMENT-COST AND SUNK-COST CONSIDERATIONS USUALLY INVOLVED

In an established enterprise such estimates are likely to involve increment-cost situations and sunk-cost situations. An increment-cost situation may be loosely described as one in which certain costs are going on regardless of which alternative is selected, but in which something more than superficial inspection is required to see that this is the case. A sunk-cost situation (really a special case of increment costs) is one in which certain expenditures or commitments already made must be ignored as having nothing to do with a choice between two alternatives for the future.

The general principle to be recognized in making cost estimates as a basis for decision between two alternatives is that no costs are relevant to a choice except those which may be expected to be different as between the two alternatives. The difficulty, however, is that there is frequently some obstacle, which may perhaps be related to the accounting routines of the business enterprise, or perhaps to the habits of thought of the estimator, which prevents the recognition of the increment-cost situation and results in irrelevant costs being considered for one alternative and not for the other one. Often this is a result of the use of average costs rather than increment costs. On the other hand, a frequent error in the opposite direction is to omit relevant costs because of a too short-run viewpoint, even though the estimator may recognize the increment-cost situation as such.

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WHAT IS THE COST OF A TRIP FROM BOSTON TO BUFFALO?

For a simple illustration of these two kinds of possible errors consider the question of determining the "cost" of making a particular trip in your automobile—to be specific, let us say from Boston to Buffalo and back. This might be a pertinent question of economy if you, owning an automobile, were contemplating such a trip and wondered if you could afford it. Or perhaps you might want to compare the cost of driving your car with the cost of railroad transportation.

Some one, keeping careful cost records, might answer this question by finding the average cost per mile of his automobile ownership and operation. Considering the cost of fuel, lubricants, tires, maintenance and repairs, insurance, taxes, storage depreciation, and interest, this average cost might perhaps turn out to be six cents per mile. On the other hand, some one else, anxious to convince himself that he could afford the trip, might recognize this as an increment-cost situation and consider the cost of the trip to be simply the immediate out-of-pocket expense for gasoline—possibly one cent per mile.

A little consideration will show that the truth is somewhere between these two estimates. If you own your automobile and intend to continue to own and operate it regardless of whether or not you make the trip to Buffalo, you are committed to many of the costs which entered into the six-cents-per-mile average, which are variable only with time and not with extra mileage. On the other hand, the one-cent-a-mile figure, which includes only the cost of gasoline, involves a too short-run viewpoint and does not recognize the ultimate effect of the trip on cost of lubricants, tires, maintenance and repairs, and perhaps to some extent on depreciation. For the sake of having a figure to discuss, let us guess that the true increment cost is three cents per mile.

INCREMENT COSTS SELDOM ACCURATELY MEASURABLE

We may use this simple example to illustrate two generalizations about increment-cost situations. The first generalization is that increment costs are seldom accurately measurable and there is often room for considerable difference of opinion as to what they may be in specific cases. The second generalization is that the term "cost" does not mean anything useful as a guide to business decisions unless it is tied down to the specific business alternatives which are being compared.

The first generalization implies that it is seldom possible to say simply on the evidence of the accounts of a business whether a decision in an increment-cost situation has turned

out to be the right one. This statement does not refer merely to the obvious fact that when you choose one of two alternatives you have by that act rejected the other one, so that the results of both are not available for subsequent comparison, but rather to the difficulty which arises because increment costs in the long run are not the same as immediate out-of-pocket expenses. For instance, if you actually make your trip to Buffalo you will be unable to determine after the trip is over exactly what later expenditures in connection with your automobile have been occasioned by the trip or accelerated by it.

Of course, if you had access to cost records of a great many automobiles you might determine average figures for the increment cost of extra mileage, but even figures so obtained would not really measure the expected increment cost in a particular case. Too many individual variables such as the driving habits of the driver, the age and condition of the car, the average annual mileage, and the car owner's policy regarding maintenance and replacement would serve to make statistically obtained averages unsuitable to a specific case.

COST MUST BE RELATED TO SPECIFIC ALTERNATIVES

The second generalization about the necessity of relating the concept of cost to specific alternatives may be illustrated by recognizing the different inferences which may be attached to the question, "What is the cost of driving your automobile from Boston to Buffalo and back?"

One inference might be that you are without an automobile but are contemplating the purchase of one for the purpose of going back and forth to Buffalo in it, and that you wish to know whether you can afford to do it, or perhaps you wish to know how the economy of the automobile compares in this situation with other forms of transportation. Here, the "cost" answer for the purpose of guiding a decision is obviously an average figure such as the six cents per mile we previously considered and rejected. A second quite different inference, the one we have placed on the question, might be that you already own an automobile and intend to continue to own and operate it regardless of whether or not you make the contemplated trip. Here, the increment-cost point of view is necessary to give the "cost" answer for comparison with some other form of transportation or for comparison with not making the trip at all. This is the cost we have guessed at three cents a mile. Still a third inference might be that you already own an automobile and wish to know whether to dispose of it or to continue to operate it for the purpose of making round trips between Boston and Buffalo. In this third case the "cost" answer is obviously considerably greater than the three-cents-per-mile figure. Many of the costs such as insurance, taxes, and storage, that are "fixed" by the policy of continuing to own and operate the car in the second case, become "variable" downward if you consider disposing of it. On the other hand the "cost" answer will probably be less than the six-cents-per-mile average in the first case if, as is likely, the car must be sold at a sacrifice price. If so, we have a sunk-cost situation, and the full interest and depreciation which would be charged against a new car would not be saved by disposing of an old one. Perhaps five cents a mile might turn out to be the right cost figure in this case. These three different situations which we have inferred in connection with this apparently simple question "What will it cost?" are being continuously paralleled in industry.

EXAMPLES OF CONFUSED REASONING

At the beginning of this article it was stated that there was evidence that incorrect reasoning was common in such situations. Limitations of space permit merely an illustration of the character of this evidence in the form of a description of two actual cases and a brief reference to the literature of three widely discussed recurrent problems of technical economy. In these illustrations it will be indicated how such errors of reasoning are frequently related to the accounting routines of a business, and how it often appears that the better the plan of accounting for its legitimate purposes, the greater the apparent likelihood of error.

ESTIMATING THE COST OF POWER

The two actual cases relate to the experience of a city which owned its electrical distributing system retailing electric energy which it bought at wholesale rates from a large power system. In the accounts of this city the expenses of the electric utility were carefully distinguished from the cost of carrying on governmental functions; the expenses of joint departments were prorated between the city government and the electric utility on an equitable basis; and the governmental departments were charged by the electric utility for electricity used at rates such as might reasonably have been charged by a privately owned corporation. Two situations arose in which this well-organized plan of accounting served to block an understanding of the increment-cost situations involved.

In the first situation the question arose as to what savings were possible by a proposed temporary reduction of street lighting as a measure of economy. The city-owned electric utility charged the general city government for street lighting energy at 2.5 cents per kilowatthour, a fair rate, all things considered. In estimating the saving from this proposed temporary street-lighting reduction, the engineer making the estimate multiplied the expected reduction in energy consumption of 80,000 kilowatthours per year by the 2.5-cent rate and concluded that the saving would be $2000 a year. Here the engineer used the average cost which he found used in the accounting system and failed to recognize that most of the items which went into the 2.5-cent rate were not variable downward with a small reduction of street lighting.

When the increment-cost situation was later recognized, it was apparent that almost the only cost which would be decreased was the cost of energy purchased at wholesale. Because of the structure of the wholesale rate, the last increment of energy cost considerably less than the average of purchased energy; in fact, less than one-third of the 2.5-cent figure previously estimated. When this real net saving to the city of about $600 in the power bill for the year was balanced against several hundred dollars of extra cost for wiring to make the change possible, it was clear that there was little or no real economy possible from the proposed temporary change and the city might as well have the benefit of the existing street lights.

In the second situation the question arose regarding the economy of the city's building its own generating station rather than continuing to purchase power. Here, in estimating the expense of the proposed generating station, the engineer's report included merely direct generating-station costs and made no allowance for increased costs in other departments. In justification of this he pointed out that overhead costs were apportioned in the accounting system in proportion to direct costs and that, as direct costs would not be increased with the proposed plant, there would therefore be no increase in indirect costs as a result of the plant.

A more realistic examination of this situation indicated that his reasoning was in the same class with assuming that the increment cost of extra miles on your automobile was merely the out-of-pocket expense for gasoline; that is, this reasoning took a too short-run viewpoint. It seemed reasonable to believe that doubling the investment in the electric utility, as

this would do, would increase the responsibility of the manager of that utility, and in the long run he would be better paid and would require an assistant sooner with the generating station than without it. It also seemed reasonable to believe that the operation of a generating station would involve more of such services as engineering, accounting, purchasing, and stores keeping than would the paying of a single power bill once a month. These conclusions were reinforced by an examination of the experience of other cities, which seemed to indicate quite definitely that expenses of these service departments always tended to increase upward with any increase in activity. From such a study it was possible to make a judgment as to what this long-run increase in expense in indirect departments would be. This item of cost had considerable weight in throwing the final decision against the generating plant which, on the basis of preliminary study, had appeared as if it might be economical.

THREE RECURRENT PROBLEMS

The first of the three recurrent problems of technical economy to be cited as evidence of frequent incorrect reasoning in increment-cost and sunk-cost situations is the much discussed one of the economic size of a manufacturing lot. This problem exists wherever a machine or production center must be used to produce more than one product or part. Although it has many complications, the essential problem involved may be described very briefly. It is the balancing of the higher preparation costs necessary with small lots which require frequent changes of the machine set-up against the increased carrying charges on the larger inventories necessary with large lots. In determining the variation of these carrying charges as between different sizes of inventories it is necessary to multiply the "values" of various inventory sizes by an interest rate (or a desired rate of return). Throughout the voluminous literature of this subject inventories are apparently always valued for the purpose of this comparison at the usual book figure which, of course, includes fixed as well as variable production costs. There is apparently nowhere the recognition that a realistic view of this as an increment-cost situation would include only the variable elements of production cost in the inventory valuation required to determine the variation in carrying charges on different lot sizes.

The second example is another problem widely discussed, the problem of when it is economical to replace a machine because of obsolescence. This is a sunk-cost problem. The sunk-cost principle is simple enough. If you accept the proposition that only those matters which are different as between two alternatives are relevant to their comparison, it should be obvious that anything which has already happened has happened regardless of which of two future alternatives is selected. Recognition of this is frequently blocked by the mode of thinking which has its origin in the conventional accounting treatment of depreciation.

In the many published discussions and formulas dealing with this question of the economy of machine replacement, the mistake of including the irrelevant item of unamortized book value of the existing machine as part of the cost of the proposed replacement machine is made more often than not. However, this mistake is by no means so universal in published discussions as the error mentioned in the lot-size problem.

The third example is from the field of highway economics. Highway engineers now recognize that in comparing the economy of alternative highway designs two groups of costs must be considered, the costs of construction and maintenance of the highway itself, which are paid by some governmental unit, and the costs of vehicle operation on the highway, which are paid by the owners of the vehicles. In considering the economy of reduced highway distance it is therefore necessary to estimate the saving in motor-vehicle operating costs. Many writers on highway economics, some of them highway officials in responsible positions, fail to recognize this as an increment-cost situation and calculate saving at an average cost per mile of motor-vehicle operation rather than an increment cost. Calculations made on this basis appear to justify many distance reductions which are not really economical. Here again, however, the error is not universally made in published discussions of the subject.

FAILURE TO RECOGNIZE INCREMENT-COST SITUATIONS FREQUENT

These illustrations from various fields, which might be multiplied if space permitted, seem to indicate the frequency of failure to recognize increment-cost situations as such. With the exception of the case of the proposed generating station for the city, all of them are comparable to the estimate of the six-cents-a-mile figure for the trip from Boston to Buffalo, rather than the true increment cost which we guessed at three cents a mile. However, examination of actual situations (as contrasted with examination of books, periodical articles, and published reports), suggests that the opposite error is quite as common in practise; increment-cost situations are often recognized as such and cost estimates made which take the same kind of short-run viewpoint as was involved in the one-cent-a-mile estimate for the automobile trip. Just as many of us like to fool ourselves by imagining that the "cost" of making a trip in a car is only the out-of-pocket expense for gasoline, so engineers and department heads within an organization may sincerely attempt to justify various proposed activities which they desire undertaken on the basis of cost figures which consider only short-run out-of-pocket expense. It is the danger that this will be done that is often responsible for the setting up of accounting routines in large organizations which involve interdepartmental charges based on average costs (such as the figure of 2.5 cents per kilowatthour in the street-lighting illustration). Such accounting routines, serving certain definite useful purposes, may nevertheless cause unwise decisions in increment-cost situations, unless their limitations are clearly recognized.

SUMMARY

In summary, where two alternatives are to be compared for the purpose of making a decision between them it is the things which are expected to be different as between them which are significant. In most decisions between alternatives which are made on the basis of cost in a going concern, it is necessary to recognize that all expenditures and commitments already made and many which will be made in the future are the same, regardless of which alternative is selected. However, it frequently happens that this is not recognized and decisions are based upon erroneous estimates of cost.

In dealing with these recurrent increment-cost and sunk-cost situations what is needed is the point of view that it is differences which are significant. This point of view is reflected in the statement that the concept of cost, in order to be a useful guide to business decisions, must be related to specific alternatives to be compared. It involves a realization that comparison of alternatives requires careful definition of what the alternatives really are and an estimate of their long-run implications. It also involves recognizing that the diversity of alternatives which must be compared in business situations is such that no routine systematic procedure, such as accounting must be even at its best, can be expected to give directly the cost figures which are needed for all comparisons.

The SELECTION *and* REPLACEMENT *of* EQUIPMENT

With Some Examples Applicable to the Woodworking Industries

By PAUL T. NORTON, JR.[1]

THERE IS naturally no way to determine just what proportion of our manufacturing equipment is obsolete and could be replaced to advantage, but there is plenty of evidence that equipment manufacturers would enjoy capacity business for a good many years if equipment users made all of the replacements that would show a net saving in total charges. The problem that faces the machine user is twofold: First, to determine what replacements are really desirable, and second, to obtain the funds for making these replacements. With even the wealthiest company there is a definite limit to the amount of money that can safely be spent at any one time for replacing equipment. The real solution of the problem is, therefore, not simply to make a replacement when it is found that this replacement is desirable, but to examine all the replacement possibilities so as to use the money that is available for those replacements that seem to show the greatest net savings.

The part of total manufacturing costs represented by fixed charges on equipment is steadily increasing. Replacements almost invariably increase fixed charges, and, unless the replacement study is made correctly, the increase in fixed charges may more than offset any decrease in operating expenses. Any decrease in the value of a machine, through ordinary depreciation or obsolescence, is certainly a part of the real cost of the products of that machine. A replacement which does not reduce total unit costs (fixed charges plus operating expenses) is undesirable from every standpoint, as it reduces employment per unit of output without any compensating advantages whatever. A manufacturer cannot afford to invest money in new equipment unless he can be reasonably certain that this equipment, during its useful life, will earn a fair return on the investment and also pay back the money invested in it.

Replacement studies can be of real use to our industries only if they are basically sound and also are expressed in such a way that they can be used by industrial executives who have not made an exhaustive study of the fundamental theories. The purpose of this paper is to outline a method for making selection and replacement studies which is sound economically and simple enough so that it can be used by any competent industrial manager.

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The method developed in this paper may be used by all industries and is not limited to the woodworking industries. The examples at the end of the paper, which illustrate the method, are taken from published studies of woodworking equipment, actual data being used wherever possible. A much more complete discussion of the subject has been published in Bulletin 32, Engineering Extension Division, Virginia Polytechnic Institute, "The Selection and Replacement of Manufacturing Equipment," by the author of this paper. Other material on the same general subject has also been published in Section 15, Machinery, written by the author for "Cost and Production Handbook," L. P. Alford, Editor, Ronald Press Company, 1934.

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REPLACEMENT BY DEFINITE PLANNING

It is unfortunate that so little attention has been paid to the definite long-time planning of equipment replacement. Both machine manufacturers and machine users would be greatly benefited if equipment were purchased at a more uniform rate. Replacement each year at a rate equal to the depreciation charged during the year would smooth out the great peaks and valleys in the production of equipment, would enable the machine user to have modern machines in his plant at all times (provided his depreciation charges were adequate), and would obviate the necessity for large special appropriations for making replacements, for which there is always difficulty in getting authority and which are sometimes difficult to finance. Articles which have been published during recent years in the technical press indicate that a number of companies have found it profitable either to replace equipment at a uniform rate under some such scheme as that just mentioned or at least to have some definite plan for making replacements. Published information also indicates that these companies replace equipment more often than is the case with the average company manufacturing similar products, further evidence that much of our present equipment would be found to be obsolete if careful replacement studies were made.

METHODS USED IN ATTACKING THE PROBLEM

The many discussions which have been appearing in technical publications are evidence of the great interest that is being shown in the replacement problem. Some of the methods that have been advocated are very complicated while others are very simple and easy to use, although many of the latter type are not at all satisfactory because of the omission or incorrect use of certain important factors.

Some investigators have entirely overlooked the fact that there is a great difference between the methods which should be used in making replacement studies and the methods which may properly be used in cost accounting to determine the costs of the various items which are produced by a machine that is actually operating. The replacement study involves a comparison of costs with two or more methods. Cost accounting involves simply a determination of the cost when using a single predetermined method. On account of this fundamental difference the cost accountant may omit certain factors, such as interest on invested capital, which must be included when making a replacement study.

In making a replacement study the proper procedure is to compare the total costs of producing a certain number of units of a certain operation by means of each of two or more pieces of equipment. Care should be taken not to make the rather common error of simply comparing the unit costs of the operation with each machine working at its capacity.

No potential advantages of a proposed machine, such as increased capacity, reduced floor space, etc., should be con-

sidered in determining the tangible factors unless these advantages can actually be realized. These potential advantages should be noted so that they may be included among the intangible factors which should always receive careful consideration.

Many formulas have been developed for use in replacement studies. Formulas have certain advantages but also have definite disadvantages because persons who do not really understand the fundamental theories may attempt to solve the problem by simply substituting in the formula. No person should use a formula, or any other mathematical tool, unless he understands the derivation. An orderly tabulation of individual and total charges, such as that developed in this paper, seems to be simpler and better than any formula that might be derived.

Tabulations and formulas give information concerning the tangible factors only, while the final decision should be based on both the tangible and intangible factors. For that reason decisions should be made by experienced executives and not by clerks. A careful tabulation of the tangible factors will aid greatly in making the final decision and remove much of the guesswork.

The method developed in this paper may be used to compare two or more machines that have been proposed for an entirely new piece of work, or to determine whether it is desirable to manufacture an article which has previously been purchased.

THE TANGIBLE FACTORS

When tabulating costs, subscripts may be used to distinguish between costs chargeable against different machines. For example, if subscripts $_1$ and $_2$ represent present and proposed equipment, respectively, I_1 and I_2 will represent investment in present and proposed equipment, respectively. By using additional subscripts any number of proposed machines may be compared with the present machine.

In the discussion which follows, let

I = the investment in present or proposed equipment. For proposed equipment this should be the total cost in place ready to operate, and for present equipment it should be the present net realizable value, regardless of the book value

A = annual percentage allowance for return on invested capital

B = annual percentage allowance for taxes, insurance, etc.

D = annual percentage allowance for depreciation and obsolescence

C = annual total cost of upkeep or maintenance, dollars

E = annual total cost of power, supplies, etc., dollars

F = annual total cost of space allotted to machine, dollars

M = annual total cost of material, dollars

L = annual total cost of direct labor, dollars

T = annual total cost of indirect labor, dollars

Y = annual total fixed charges = $I(A + B + D)$, dollars

R = annual total charges of all kinds against machine for producing expected output. $R = Y + C + E + F + M + L + T$

In making replacement studies it is necessary to determine the fixed charges on both present and proposed equipment. There is no difference of opinion with regard to what the investment is in the case of proposed equipment. Every one will agree that the fixed charges on the proposed equipment should be based on the total cost in place ready to operate. There are three possible values that might be used for the investment in the present investment: First, the original cost; second, the book value; third the realizable value, which may be scrap value, second-hand value, or value to the same company for some other purpose. It is clearly incorrect to use the first cost, as equipment is certainly under no obligation to earn a return on that part of its original cost which has already been written off through depreciation. If fixed charges on present equipment are based on the original cost the results of the study will be unduly favorable to making the replacement, because these higher fixed charges will make the cost of continuing to use the present equipment appear higher than it actually is.

The same reasoning applies to basing fixed charges on the book value. The book value is simply the difference between the original cost and the depreciation that has already been charged. No matter how carefully prepared, depreciation rates and book values are merely estimates. The actual depreciation which *should have been charged* as a part of the cost of the products of the equipment becomes known only when the equipment is displaced. In making a replacement study we are interested in determining what the result will be if the replacement is made, therefore the only reasonable procedure is to base the fixed charges on the realizable value of the present equipment.[2]

Attention will now be called to a serious error which has the effect of unduly penalizing the proposed equipment. When equipment is replaced before it reaches the end of its originally estimated life, its book value will generally be higher than its realizable value. Most persons who have published material on this subject argue that the capital loss which seems to occur at this time is caused by the replacement, and that any such loss should be charged against the new equipment. Such a procedure is entirely incorrect. The fact of the matter is that any difference between the book value and the realized value of replaced equipment represents additional depreciation which actually occurred during its life and which *should have been charged* as a part of the cost of the products of the replaced machine. It may not have been a loss at all. The replaced equipment may easily have been so profitable that there was a net profit even after the total *actual* depreciation was charged against it. To charge any such past losses, even if real, to future costs is just as unthinkable as for a company to charge a loss on some particular manufacturing order to the *cost* of some particular future order.

EXPECTED RETURN ON INVESTED CAPITAL

There can be no doubt that some charge for the use of capital should be included in replacement studies. The several machines that are being compared almost invariably require different capital investments, and unless some charge is made for the use of capital the study will give a result that is unduly favorable to the machines which require the larger amounts of capital. The method for charging for the use of invested capital which is developed in this paper seems to the author to be simpler and more logical than methods which have been advocated in other discussions of the subject.

It is here proposed that in making a replacement study the capital investment required for each equipment should be charged with that rate of return which would make the in-

[2] If it should happen that the replacement study fails to justify the replacement and the present equipment is retained in service, there would seem to be no necessity for writing down the book value so as to agree with the realizable value that was used in the replacement study. The fact that the replacement has been shown not to be desirable proves that the present equipment has not reached the end of its economic life, and realizable value for some other purpose no longer is a factor. However, the fact that consideration has been given to the replacement indicates that the equipment is probably nearing the end of its economic life. A new estimate should be made of the remaining life and a new depreciation rate set accordingly.

vestment attractive when consideration is given to the risks that seem to be inherent in that particular investment. (Depreciation and all other real costs will be taken care of separately and therefore should not be considered in any way in setting this rate.) This is a rather novel idea, but it merely means that we definitely charge each investment with the expected rate of return or profit for which we would be willing to make the investment. This may be thought of as the rental value of money used in this particular way. When the real costs due to the other factors are added to this investment charge, the sum will give the total charges against the particular equipment. How these total charges should be handled will be explained later.

It is here assumed that most companies will wish to figure depreciation by the straight-line method, in which case the investment will decrease each year and it is proper to figure the investment charge on the depreciated value. An average rate of return can easily be determined which, when multiplied by the original investment, will give the average investment charge per year for the estimated life of the equipment. If A' is the desired rate of return and N is the estimated life in years, then factor $A = \frac{1}{2} A' \left(\frac{N+1}{N}\right)$. It will be noted that A is equal to A' for a life of one year, is equal to $\frac{3}{4}A'$ for a life of two years, and approaches $\frac{1}{2}A'$ for a long life.

If the sinking-fund method of charging depreciation is used in the replacement study, the charge for the use of capital must be made at the full rate on initial amount of capital during the entire estimated life, because with the sinking-fund method the depreciation payments must remain in the sinking fund at compound interest during the entire period and cannot be used to reduce the investment against which a return must be charged.

Factor B needs no particular explanation. This factor should be corrected in the same way as factor A, in order to get the average annual cost with decreasing investment.

DEPRECIATION AND OBSOLESCENCE

Equipment is not only expected to earn a return on the investment while it is in use but also to earn an amount which will repay the loss in value of the equipment during its economic life. In a replacement study the depreciation rate should be based upon the period during which the machine is expected to pay for itself. For instance, if the machine is expected to pay for itself in four years, the depreciation rate (with straight-line depreciation) will be 25 per cent. This depreciation rate will usually be higher than the depreciation rate that will be used if the machine is actually purchased. This depreciation rate should be high enough to include the decrease in value through ordinary depreciation and also the danger of loss through possible obsolescence.

No attempt has been made to allow for a possible salvage value at the end of the economic life. To do so would simply add another uncertain factor of very small magnitude without any particular advantage in obtaining the final result.

OTHER FACTORS

Factor F is included because different machines may require different amounts of space. This factor includes fixed charges on land and buildings (with non-productive equipment such as cranes, etc.); also such items as heat and light. In fact it includes all of the overhead costs not definitely included in any of the other factors. Care should be taken not to credit a proposed machine with any potential saving in floor space unless the space that is released can be used for some other productive purpose.

There will rarely be much change in indirect labor (factor T) on account of a machine replacement, but a careful estimate of just what the indirect-labor cost will be with each equipment would certainly seem to be worth while. Many companies figure total overhead as a percentage of direct labor. This approximate method of charging overhead may be fairly satisfactory in many instances, but it is certainly not proper to assume that either indirect labor, or overhead in general, will decrease in the same proportion as the decrease in direct labor that may result from a machine replacement.

In replacement studies where it is apparent that there will be little or no change in certain of the factors, some time may be saved by omitting these factors. The difference between the values of the total charges R will not be changed by the omission of these factors in cases of this sort, but R will no longer represent the total charges.

GENERAL DISCUSSION

After the total charges against each equipment have been calculated, it is a simple matter to determine which equipment shows the lowest total charges, no matter how many machines are being compared. As each machine has already been charged with the rate of return on invested capital and the depreciation rate for which it has been decided that the investment would be desirable, the replacement would seem to be in order if the proposed machine or any one of them shows a further net saving. It is here assumed that a general survey has been made of all cases where a replacement might seem to be desirable so that the available funds may be used where they will produce the greatest net savings.

In the present method no attempt has been made to determine how much money one can afford to invest in a proposed machine, how soon the machine will pay for itself, or what the rate of return will be on the additional investment. The method herein outlined gives all of the information that could be obtained if any or all of these items were calculated and does it more simply and more accurately.

There is no need to determine how much money one can afford to invest in a proposed machine. Either the cost is already known or it can be estimated, and the real problem is to determine whether the machine will show an attractive saving after all charges have been assessed against it.

There is no need to determine how soon the machine will pay for itself. A decision should be made as to the period during which the machine will be expected to pay for itself, and the machine should then be charged with a depreciation rate that will force it to pay for itself (plus a return on the investment) during that period.

There is no need to determine the percentage return on additional investment if, as in the present method, each investment is charged with a return on invested capital which would make the investment attractive. The essence of the present method is to charge every investment with the percentage return required to make that investment attractive and then to determine whether the savings in total charges with the proposed machine are worth while. These savings may just as well be in dollars as in a percentage return on additional investment.

In this discussion the replacement problem has been considered from the standpoint of cost alone. There may be many other reasons for making replacements.

FUNDS FOR MAKING REPLACEMENTS

A full discussion of the different methods that may be used in securing funds for making replacements is beyond the scope of this paper, but it may be well to refer briefly to several phases of this particular problem. Attention has been called by several

investigators to the fact that under usual accounting procedure the amount of money which is charged against equipment for depreciation never appears on the books as cash which is to be used for replacing this equipment; also that boards of directors may refuse to authorize replacements that are desirable, simply because there are no liquid assets which have been set aside for this particular purpose. To overcome this difficulty, it has been suggested that companies should set aside each year an amount of cash equal to the depreciation that has been charged and that this money should be used for no other purpose than the replacement of equipment. There are decided objections to this proposal, at least in the way it is usually described. This replacement fund would naturally be invested in what were considered safe securities, the return on which would be less than the interest rate at which the company was borrowing money, so that it would seem better for the company to use these funds in its own business until the time came for making the replacements. The best way to handle this matter would seem to be a policy of continuous replacement, replacing equipment each year to the extent of the *actual* depreciation of existing equipment.

EXAMPLES OF MACHINE SELECTION OR REPLACEMENT

In the examples which follow, actual data have been taken from published studies for the first cost of machines and also for operating costs. Depreciation rates and rates of return on invested capital have been assumed, as well as the age and realizable value of present equipment. In the tabulations of charges all items have been listed, but values have had to be omitted for certain factors where no information was available in the published studies. It is reasonable to assume that there will be no great difference between the machines for these particular items, in which case their omission will not have much effect on the final result, although the total charges will not be available.

EXAMPLE 1

A furniture manufacturer is considering the installation of an automatic machine for boring holes in wood, to replace two machines of the same total capacity. The proposed machine will cost $1200 ready to operate and will be expected to return its investment in three years while earning a return of 15 per cent on the average investment. The present machines cost $650 each and are five years old. The life of the present machines was estimated as ten years, the book value is $325 each, but the realizable value is only $175 each. The fixed charges on the present machines will be based on realizable value, assuming the remaining life as three years and charging a 15 per cent return on average investment during that period. The remaining life of the present equipment is set at three years because it does not seem reasonable to assume a longer life for a present machine than the period during which the proposed machine is expected to pay for itself. Insurance and taxes are 2 per cent on average investment. In this case

$$A = \tfrac{1}{2} \times 0.15 \times \frac{3+1}{3} = 0.10$$

$$B = \tfrac{1}{2} \times 0.02 \times \frac{3+1}{3} = 0.013$$

The figures in Table 1 indicate that the proposed machine will show savings that will not only pay back the increased investment in three years, while earning a return on the average investment during that period, but will show additional savings in total charges of $920 per year. If the proposed equipment proves to have a life greater than three years, the saving in total charges will be more than $920 per year. If the replacement is made, the difference of $300 between book value and realizable value for the two present machines should be charged to profit and loss, to surplus, or to a replacement fund.

TABLE 1

Factor	Present equipment, 2 machines	Proposed equipment, 1 machine
I	$350	$1200
A	0.10	0.10
B	0.013	0.013
D	0.333	0.333
$A+B+D$	0.446	0.446
Y	$350 \times 0.446 = 156$	$1200 \times 0.446 = 534$
C	50	35
E	149	110
F	8	4
M	...	...
L	2480	1240
T	...	...
R	$2843	$1923

EXAMPLE 2

A furniture manufacturer requires an additional machine for a certain operation. Two machines are being compared, one costing $1226, which has just the capacity required at present, and the other an automatic machine costing $2864, which has twice the capacity required at present. No credit will be given the automatic machine for its extra potential capacity. The machines will be compared on the basis of a five-year life, and a 12-per cent return on average investment. Insurance and taxes will be figured at 3 per cent. Here

$$A = \tfrac{1}{2} \times 0.12 \times \frac{5+1}{5} = 0.072$$

$$B = \tfrac{1}{2} \times 0.03 \times \frac{5+1}{5} = 0.018$$

TABLE 2

Factor	Hand machine	Automatic machine
I	$1226	$2864
A	0.072	0.072
B	0.018	0.018
D	0.20	0.20
$A+B+D$	0.29	0.29
Y	$1226 \times 0.29 = 355$	$2864 \times 0.29 = 830$
C	50	25
E	193	250
F	15	21
M	...	...
L	1857	680
T	...	...
R	$2470	$1806

The figures in Table 2 indicate that even with the automatic machine idle half the time there will be a saving in total charges of $664 per year. It can easily be shown that if the automatic machine were compared with two hand machines, for full operation of the automatic, the saving in total charges would be $2179 per year. No credit was given the automatic machine for potential capacity which cannot be used at present. This is conservative practise, but it is evident that if the total charges on this basis had been approximately equal, this extra potential capacity—an intangible factor—might have been the deciding element.

EXAMPLE 3

A woodworking company finds it necessary to increase its cut-off saw capacity. This may be done either by installing an

(*Continued on page 629*)

HYDRAULIC VALVES *and* GATES *for* BOULDER DAM

Part III—The Design and Fabrication of the Needle Valves and Paradox Emergency Gates

By P. A. KINZIE[1]

THE NEEDLE VALVES

AFTER THE 30-ft penstock headers have reached the last of the 13-ft branches at their downstream ends, they are reduced to 25 ft in diameter and are continued as outlet headers in their respective tunnels to the needle-valve outlets as shown in Fig. 1.

The 25-ft outlet headers in the high-level tunnels on opposite sides of the river gorge at elevation 820 (see Fig. 2) lead to the manifolds which feed the canyon-wall outlets. Each consists of a battery of six 84-in. needle valves installed in reinforced-concrete valve houses built into recesses blasted into the solid rock of the river-gorge walls, with the center lines of the valves 195 ft above low-water level.

In Fig. 3 the recess blasted out of the canyon wall for the valve house on the Arizona side of the gorge may be seen, with the rock bench on which the reinforced-concrete floor and anchorages for the needle valves will be laid. The ends of the 102-in. steel outlet pipes from the upper outlet manifold protrude from their individual tunnel portals in the rock face. The vertical recess cut into the rock wall at the left is for the elevator shaft which continues downward nearly 200 ft to a communication adit leading to the power plant and tunnel-plug outlet works.

Both these valve houses are substantially alike as to arrangement and size. They are 202 ft long inside, by 33 ft wide, as may be seen in the sectional plan of Fig. 4, which shows the outlet-header manifold with the six 102-in. outlet pipes extending from the manifold to the needle valves, and in section *B-B* which shows the arrangement of the valves and their protecting Paradox emergency gates.

Each valve house is provided with a 30-ton overhead traveling crane which serves the valves and gates, and a passenger elevator operating in a vertical shaft cut into the rock and communicating with the tiled galleries below, which extend from the power house to the tunnel-plug outlets. A front elevation of the valve house on the Arizona side of the gorge is shown in Fig. 5. A sectional plan in the same illustration shows the arrangement of the valves with their discharge guides and the Paradox emergency gate behind each needle valve.

The upper construction adits leading to the 37-ft tunnels for the high-level outlet headers are but a short distance upstream from both these valve houses. Roadways extending between the landing platforms at these adit portals and the upstream ends of the valve houses are provided. By this means the 150-ton permanent cableway can land heavy machinery and equipment upon a special car placed on either of the landing platforms. This car is then pulled by special winches up inclined tracks to each valve house.

The twelve 84-in. valves comprising these two batteries are all manually controlled individually by means of a control stand located on the operating balcony above each valve as shown in Fig. 6. In this figure the longitudinal section shows one of these valves wide open. The control stand on the concrete balcony above the valve may be seen, with the interconnecting control shaft extending downward to and through the valve to the Paradox control bolted to the flange on the under side of the valve body. Fig. 6 also shows the piping and connections bringing the pressure supply to this control, the control exhaust piping, the drainage piping from the Paradox emergency gate, and the gate itself, which is encased in heavily reinforced concrete.

The heavy plate-steel discharge guide bolted to the valve-nozzle flange and extending to the orifice liner through the valve-house wall is also shown. These discharge guides and their orifice liners are made sufficiently greater in diameter than the jets from the needle valves so as to provide an annular air space of ample area between the exterior surfaces of the jets and the interior surfaces of the guides to insure the suppression of reverberatory make-and-break effects.

Each valve is supported by and anchored to bifurcated concrete piers in the manner shown in the view of the inlet end of the valve, Fig. 6, which likewise shows the inverted U-shaped standpipe to which the exhaust from the Paradox control is connected. This standpipe insures that the interior hydraulic chambers of the valve will always be filled with water. By this means the possibility that these chambers will drain and trap air with the explosive effects which the presence of air produces under certain conditions of operation is avoided.

In the end view of Fig. 6 the air-vent-breather manifold and its interconnecting piping to the chambers and cavities within the valve appear to the left and just above the upper portion of the valve. This manifold contains three similar automatic air valves which allow air to escape from the interior of the valve when it is being filled with water at the beginning of the operating season. These close as soon as the air has been driven out and water attempts to pass through them. The air valves open automatically and admit air to the interior of the valve when it is being drained at the end of the operating season. This is done by opening the drain valve built for that purpose in the Paradox control, and then opening the gate valve between the vertical legs of the standpipe. When this is done, and the valve in the drain line beneath the needle

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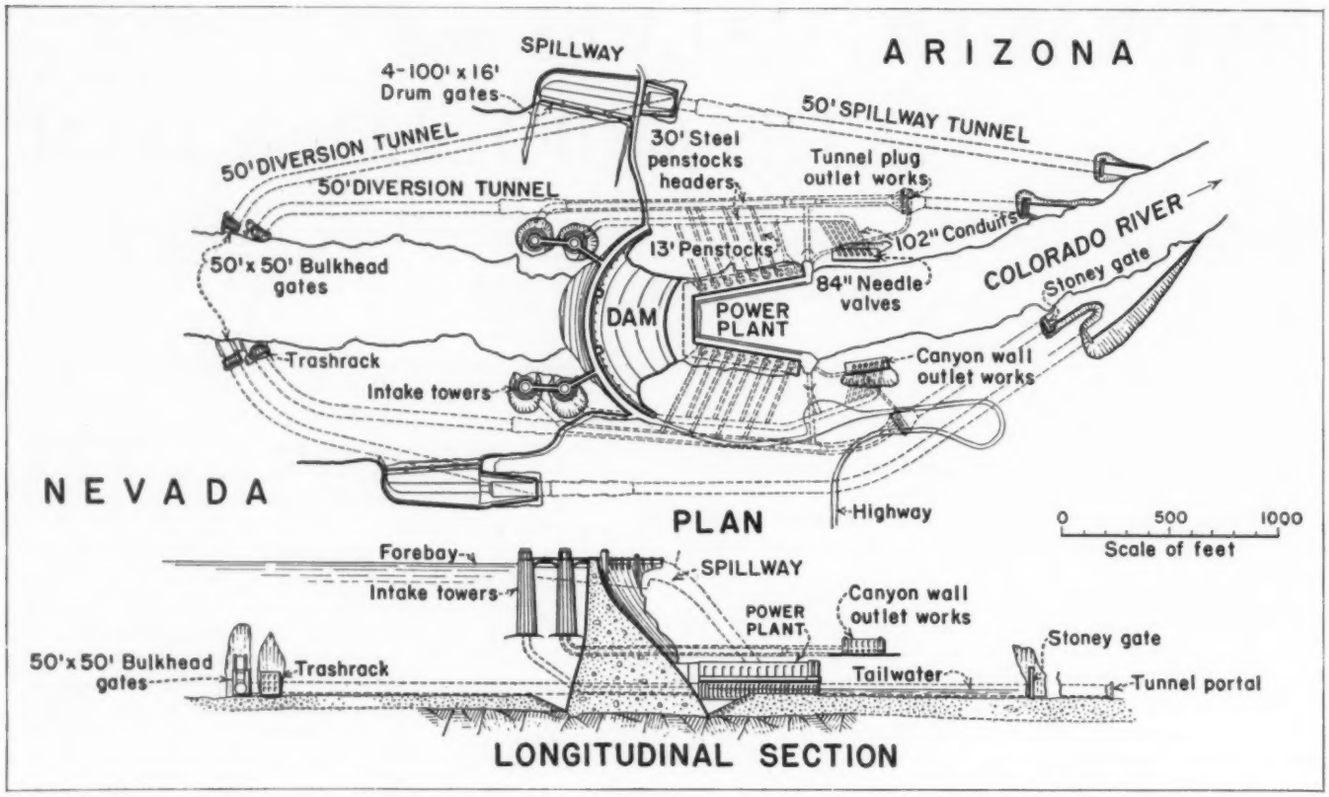


FIG. 1 PLAN AND LONGITUDINAL SECTION OF BOULDER DAM AND ASSOCIATED WORKS

valve from the low part of its water passage is opened, all the interior of the needle valve will drain.

The valves are operated and controlled by means of water pressure in the conduits to which they are attached. The pressure line to the Paradox control beneath the valve supplies water under pressure which this control admits to port passages within the valve leading to chamber *A* in the longitudinal sections of Figs. 6 and 7 when opening movement of the needle is desired, and to chamber *B* when closing movement is to be effected. Referring to the longitudinal section showing the valve wide open, Fig. 6, it will be evident that if the control is set to admit pressure into chamber *B*, this will cause the needle to move toward the right until it eventually reaches the position shown in Fig. 7 and the valve will then be closed.

Further inspection of these two views will make it evident that as the needle moves from the open position to the closed position, the water in chamber *A* will necessarily be expelled. This water flows through the intercommunicating passage-ways provided in the valve body, passes through the control of the Paradox valve, and finally into the exhaust line below.

By reversing this procedure and adjusting the Paradox control so as to admit pressure into chamber *B* with the valve in the closed position, Fig. 7, the needle will move to the left to the wide-open position shown in Fig. 6.

All water used to operate the needle in either direction passes through the Paradox control into the proper chamber to secure the movement desired thereby, and all of the water that is released from the inactive or passive chambers of the valve flows outward through this control and into the drain line below.

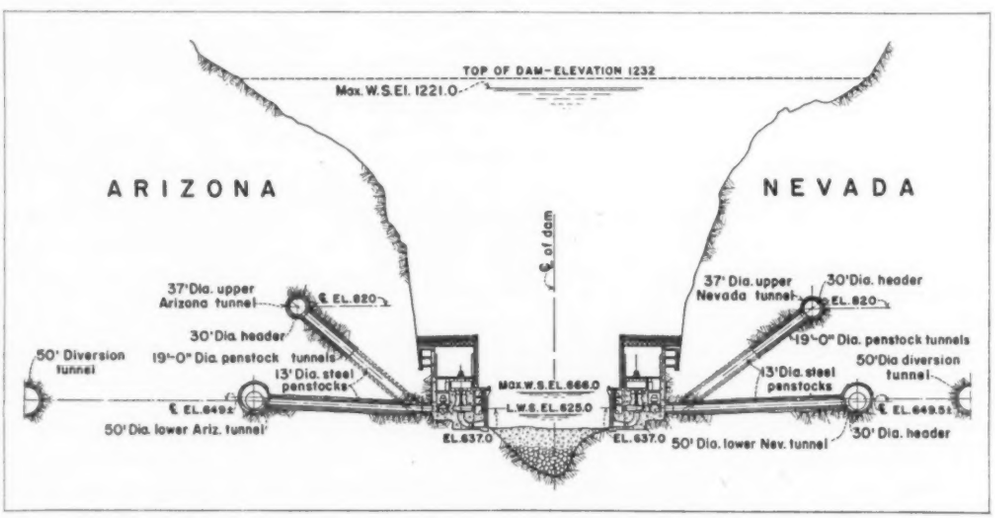


FIG. 2 CROSS-SECTION THROUGH THE TWIN WINGS OF THE POWER PLANT AND THE ADJACENT CANYON WALLS, SHOWING THE RELATIVE LOCATIONS OF THE UPPER AND THE LOW-LEVEL PENSTOCK HEADERS

In Fig. 8 a vertical longitudinal section through this control is shown in section *A-A*. It will be seen that the active element of this mechanism consists of a three-spool piston valve working vertically in a bronze liner provided with five ring ports. The center port is the pressure inlet, the one above leads to the passageway within the needle-valve opening into chamber *A*, and the one below communicates with passageways within the needle valve to chamber *B*. The uppermost and the lowermost ports are exhaust ports interconnected as shown in section *B-B*.

The center shaft shown in these views is manually operated from the control stand above and as it is turned it rotates the driving spider below the piston valve. This causes the special nut with quadruple acme thread to turn and carry the piston valve up or down. The upper end of this threaded member is connected to a tubular shaft which extends upward into the needle valve. Here, on the horizontal centerline of the valve, the shaft is provided with a spur pinion engaging with the teeth of a bronze rack attached by a tubular member to the forward portion of the needle as shown in Fig. 9.

FIG. 3 RECESS BLASTED IN THE CANYON WALL IN WHICH THE NEEDLE-VALVE HOUSE AND THE CANYON-WALL OUTLET WORKS WILL BE BUILT

(Six 102-in. steel pipes which will bring the water to the needle valves are shown protruding from their tunnels.)

By this arrangement the movement of the needle in either the opening or the closing direction causes the rack to move with it and so rotates the meshing pinion, its tubular shaft, and the threaded member attached to the lower end of the shaft in the control below. When this occurs the rotation of this threaded member causes the nut mounted upon it and the piston valve enclosing it to move vertically in the opposite direction to that previously caused by the manual rotation of the center shaft from the control stand above. By this arrangement motion of the piston valve by manual means is counteracted by the responsive movement of the needle.

The total actual vertical travel which the piston valve can make is limited to $2^1/_4$ in., while the needle, in traveling from the open to the closed position or vice versa, causes rotation of

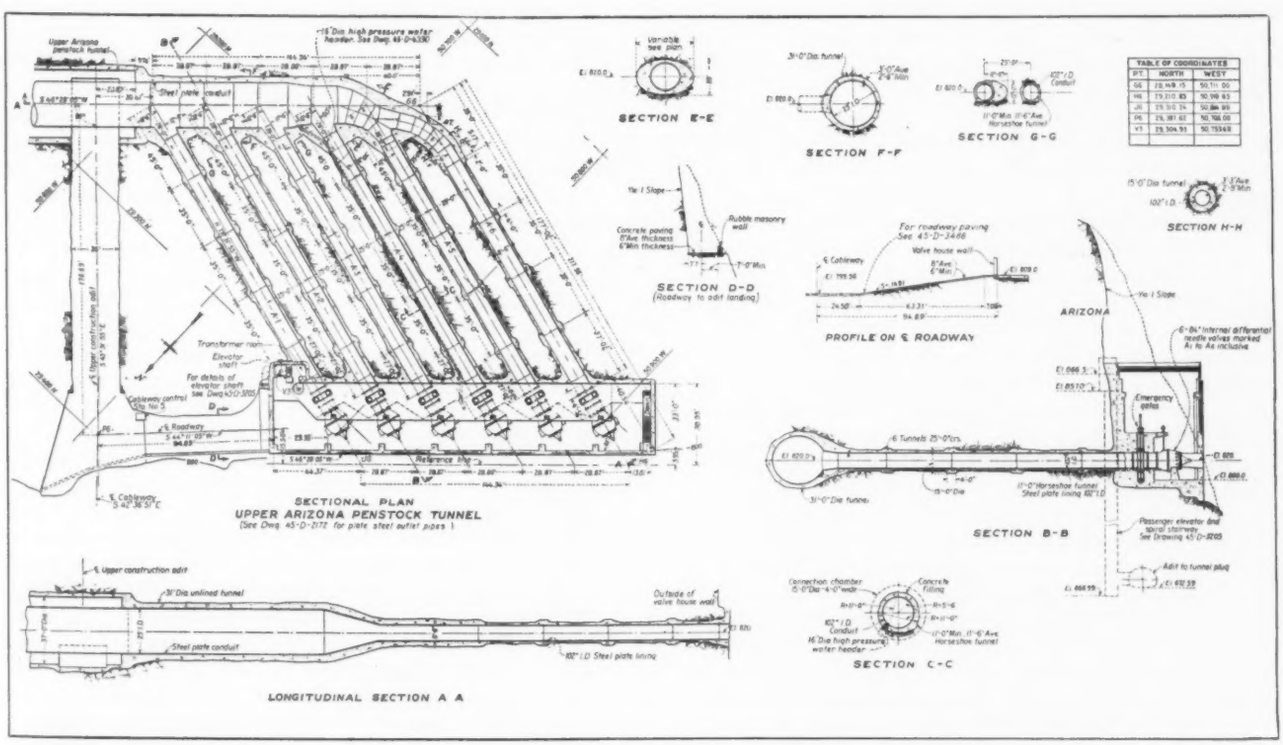


FIG. 4 SECTIONAL PLAN OF THE OUTLET MANIFOLD AND THE SIX 102-IN. OUTLET PIPES LEADING TO THE NEEDLE VALVES IN THE CANYON-WALL OUTLET WORKS, ARIZONA SIDE

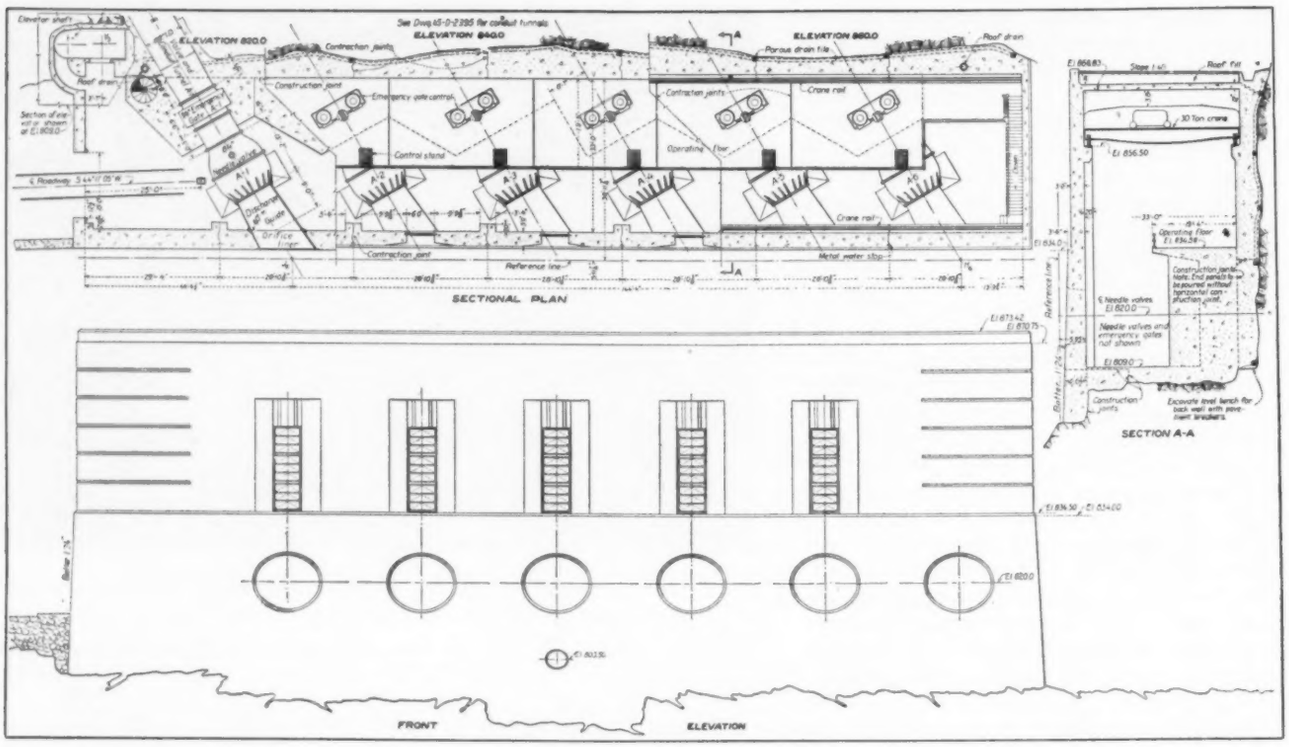


FIG. 5 SECTION PLAN THROUGH VALVE HOUSE AND FRONT ELEVATION SHOWING THE OVAL ORIFICES IN BUILDING WALL THROUGH WHICH THE JETS FROM THE NEEDLE VALVES WILL PASS

the central threaded member sufficient to produce many times this limited travel of $2^1/_4$ in. Here a paradox occurs, for as soon as a small portion of the total travel of the needle has absorbed this $2^1/_4$ in. of vertical movement of the piston and its nut, further movement of the needle is then accompanied by pure rotary motion of the screw and the nut, thereby insuring safety to the parts.

This rapid travel of the piston valve makes the needle very sensitive and responsive to the controls, so that no difficulty is experienced in moving the needle to any desired position with the utmost precision, and the control will then automatically maintain the needle in that position indefinitely.

The general construction of these needle valves may be seen in the longitudinal section of Fig. 9. The body and nozzle are steel castings weighing 43,920 lb and 51,000 lb each, respectively, before machining. The needle head and the diaphragm, the needle cone and tip, and the body tip are also steel castings. The diaphragm tube and the needle are manganese-bronze castings. One needle casting before machining weighs 16,910 lb.

Fig. 10 shows two 84-in. internal differential needle valves similar to those which will be used at Boulder dam. These valves were built in accordance with the Reclamation Bureau's designs and specifications by the Lake Erie Engineering Co. and are being given a shop pressure test prior to their shipment to the Panama Canal for installation at Madden dam, Panama Canal Zone. The two valves shown here will be used under much lower heads than those at Boulder dam. Fig. 11 shows the valve-nozzle casting with the needle and needle head in place in the bore and the bronze diaphragm tube protruding to the left through the needle head.

All surfaces of parts in contact with other moving surfaces are either bronze or are bronze faced on account of corrosion. Particular care has been given to the design and construction of these valves in order that all moving and contacting surfaces may be readily accessible, for it has been found essential to scrape away the incrustations that are deposited upon such surfaces in order that such portions of their mechanisms as are immersed in water may function satisfactorily.

The needles of these valves may be moved to any desired position or changed to different positions during maintenance operations by means of the Paradox controls, with the conduits dry leading to the valves. Access to the interior of the valves may be readily secured by the removal of the body or needle tips, and the needle, needle head, and diaphragm tube may be entirely removed from and replaced in the valve without dismantling the valve body and nozzle.

The total working head on these valves, including the pressure rise, is 427 ft and they are designed for a working pressure of 185 lb per sq in.

The working clearances required to secure proper operation are exceptionally small and in consequence of this fact the uniform distribution of stresses in order to avoid distortion and consequent binding requires very careful attention in design. These small clearances likewise make periodic inspection and maintenance work in the form of scraping all working surfaces clean a most essential procedure.

The twelve 84-in. valves comprising the two canyon-wall outlets are capable of discharging 48,000 cfs when operating at maximum capacity which is equivalent to 4000 cfs per valve.

The energy of the falling water from each of the twelve streams will be in excess of 90,000 hp, or a total of well over a million horsepower for the twelve, while the energy controlled by each valve as the water leaves the nozzle will be an additional 193,000 hp per valve or 2,300,000 hp for all twelve, and the total energy involved including the drop to the river will be over 283,000 hp per valve or in excess of 3,300,000 hp.

The primary purpose of these two canyon-wall outlet bat-

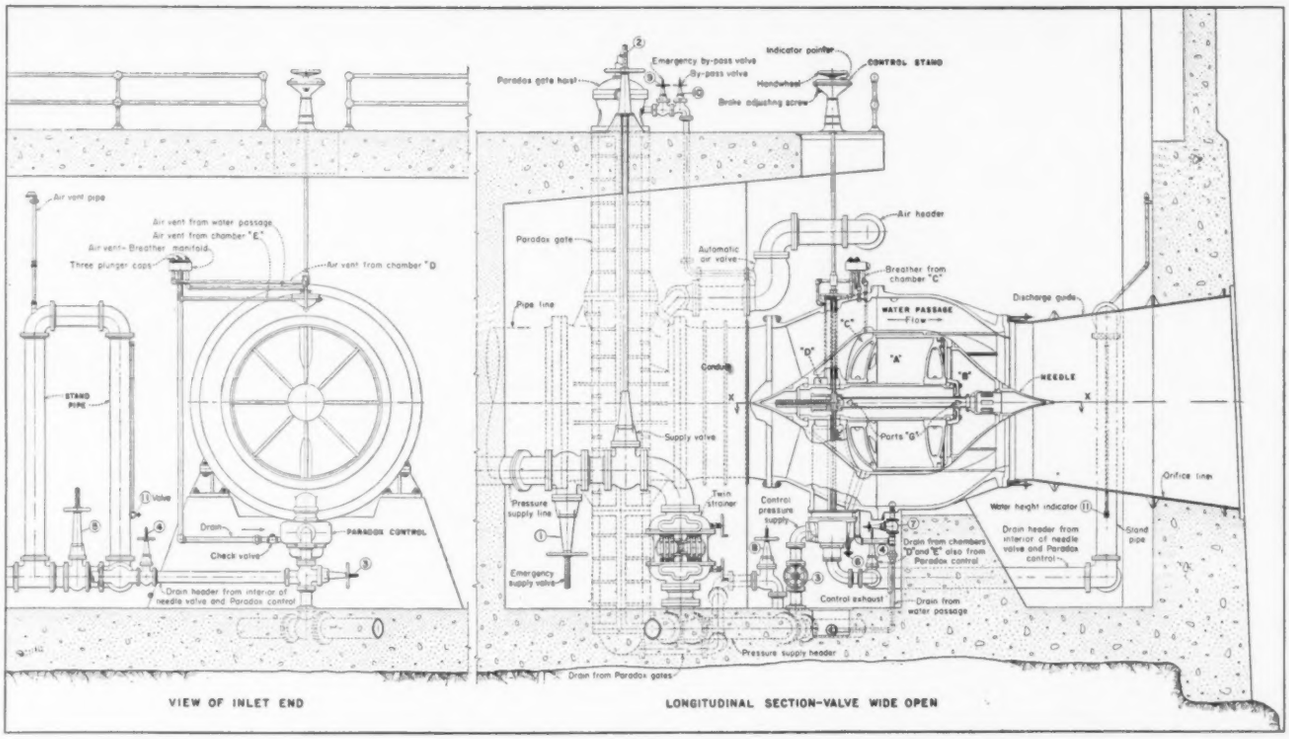


FIG. 6 TYPICAL NEEDLE-VALVE INSTALLATION WITH THE ASSOCIATED CONTROL, DRAINAGE, AND AIR-VENT PIPING AND THE PARADOX EMERGENCY GATE PROTECTING THE NEEDLE VALVE

teries is to draw down stored water in the reservoir in anticipation of an oncoming major flood, so that when this flood does arrive there will be ample flood storage available within the reservoir and the flow of the river can be held within bounds.

Needle valves similar to those in the canyon-wall outlets will be installed in the tunnel-plug outlets (see Fig. 1) located in the inner diversion tunnels on each side of the river. The centerlines of these valves will be level with the centerlines of their respective 50-ft diversion tunnels at approximately elevation 653, which is 28 ft above low-water level in the river.

There will be six 72-in. valves in each of the two tunnel-plug outlets in the general manner illustrated in Fig. 12. As will be seen in the plan view of Fig. 12, the 50-ft tunnel has been widened to provide an operating room 114 ft 6 in. long by 34 ft 6 in. wide with a vaulted ceiling cut into the rock to clear a 20-ton traveling crane serving the needle valves and their Paradox emergency gates. In Fig. 13 the excavation in diversion tunnel No. 2 for the tunnel-plug outlet works is shown partially completed.

Fig. 12 shows how these valves are aligned so that their jets will converge toward the center of the tunnel below and how the widened portion of the tunnel below the downstream walls of the valve chamber converges and merges into the original 50-ft tunnel below. It will be noted that the valves are connected in pairs by three wye branches of welded plate steel from which three feeders extend upstream to join the main three-way wye at the lower end of the 25-ft outlet header.

These 72-in. tunnel-plug valves are capable of releasing 42,900 cfs when they are all working at maximum capacity. They will be subjected to a total head of 603 ft, and are designed for a maximum working pressure of 300 lb per sq in. The general construction and the interrelationship of the parts are practically identical with those of the canyon-wall outlets. Each of the six valves in one of these batteries will be releasing water possessing potential energy of 234,000 hp, which makes a total for the six of 1,404,000 hp liberated into an oval 82-ft broad by 50 ft high.

Every possible precaution was taken in order that the design of these tunnel-plug outlets might be prepared with even reasonable assurance of adequacy and safety for the performance of the tasks involved. Model tests were started at an early date under the supervision of E. W. Lane, research engineer, who performed most of the work in the hydraulic laboratories of the Colorado Agricultural College at Fort Collins and in the field laboratory at Montrose, Colo.

The first tests were made with tapered nozzles formed on the ends of tubes to produce jets on a small scale in simulation of

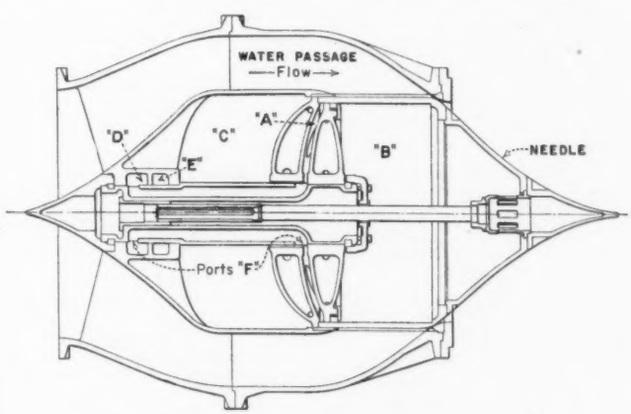


FIG. 7 SECTION OF NEEDLE VALVE IN CLOSED POSITION (Ports *F* communicate with chambers *D* and *A*. Ports *G* communicate with chambers *E* and *B*.)

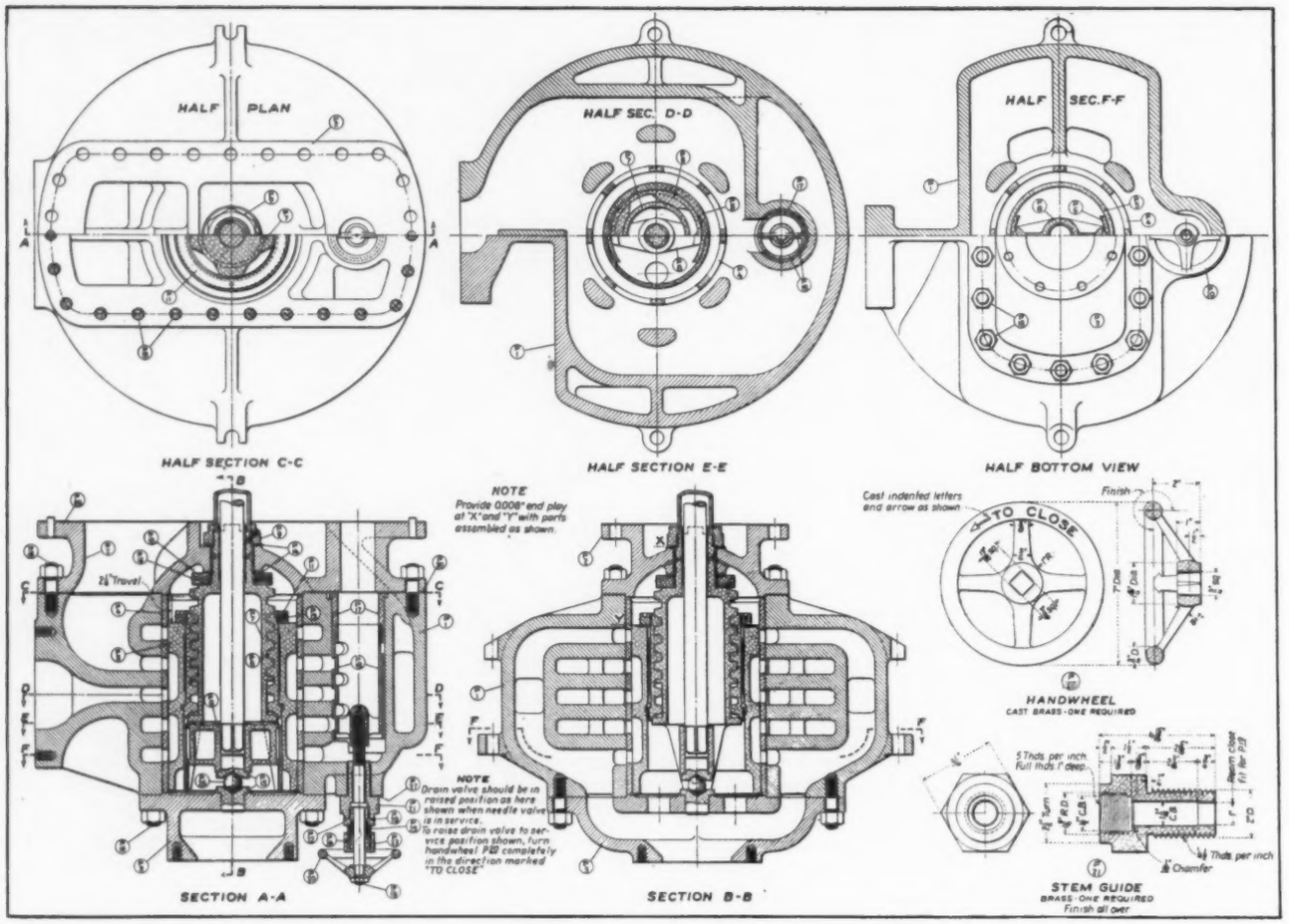


FIG. 8 SECTIONAL ASSEMBLIES OF THE PARADOX CONTROL MECHANISM

the needle valves. These sets were discharged into a pyralin tube representing the 50-ft tunnels, and many unexpected results developed almost immediately.

It was found that this model was very sensitive to minute deviations from symmetry and alignment of the jets, which would, in certain instances, pile the water up in the tunnel and in other cases cause swirls of it around the walls and roof.

Models of actual needle valves were then made on a considerably larger scale (1:12) and set up in the special hydraulic field laboratory at Montrose, Colo., where the increased volume of water required for these was available. These tests were carried to still further refinements of detail. Numerous trial runs were made with various settings of the needles in single and double planes and with varying horizontal and vertical angles of the converging jets until the most favorable setup was found. During these tests at Montrose the air conditions within the closed tunnels in front of the valves were carefully studied. Upon completion of these tests an accurate scale model (1:60) of the three sets of wyes and the main triple-wye connection to the outlet header were prepared, including accurate replicas of the needle valves and their shut-off gates (Fig. 14). Fig. 15 shows this model undergoing tests in the Fort Collins hydraulic laboratories, with the converging jets discharging into a pyralin tunnel tube which permitted observation of the actions occurring within through its transparent walls.

Through these tests the correct horizontal and vertical angular settings of the valves were finally established at Montrose and confirmed by tests of the smaller model at Fort Collins, as was also the fact that the valves must be operated in pairs to preserve hydraulic balance and symmetry of flow through the tunnels.

The model testing of these tunnel-plug outlets convincingly demonstrated the value of such procedure and confirmed the desirability of employing this type of investigation on the intake towers, where its use showed how a saving of many thousands of dollars could be made in their construction without impairing their efficiency or safety, and on the side-channel spillways, and many other structures, including the penstock-header systems.

The needle valves in the tunnel plugs are being provided with interlocking remote-electric-control equipment with selsyn position indicators so that they can be operated from the central control pulpit in the power plant.

The 72-in. needle valves in the tunnel-plug outlet works and the 84-in. needle valves in the canyon-wall outlet works embody the principle conceived by O. H. Ensign in 1906, when, as chief mechanical and electrical engineer of what was then known as the Reclamation Service, he was confronted with the problem of releasing large volumes of water from deep reservoirs.

There are many needle valves in use which are larger than those which have been described, notably the 21-ft valves installed as shut-off valves in the penstock adjacent to the 70,000-hp turbines at Niagara Falls, but it is believed that the

installation at Boulder dam is by far the largest known for the free-discharge type of service.

PARADOX EMERGENCY GATES

Because of the high heads and exceptionally severe operating conditions which all these valves at Boulder dam must meet, each is provided with individual shut-offs to permit maintenance work and periodic inspection without having to shut down the cylinder gates in the intake towers. These shut-offs are known as Paradox emergency gates, two sizes of which are employed. Those in the tunnel-plug outlet works behind the 72-in. needle valves are 86 in. in diameter, while those protecting the 84-in. needle valves in the canyon-wall outlet works are 96 in. in diameter. Except for this difference in size the gates are essentially alike and the description of the 96-in. will apply to the 86-in. gates.

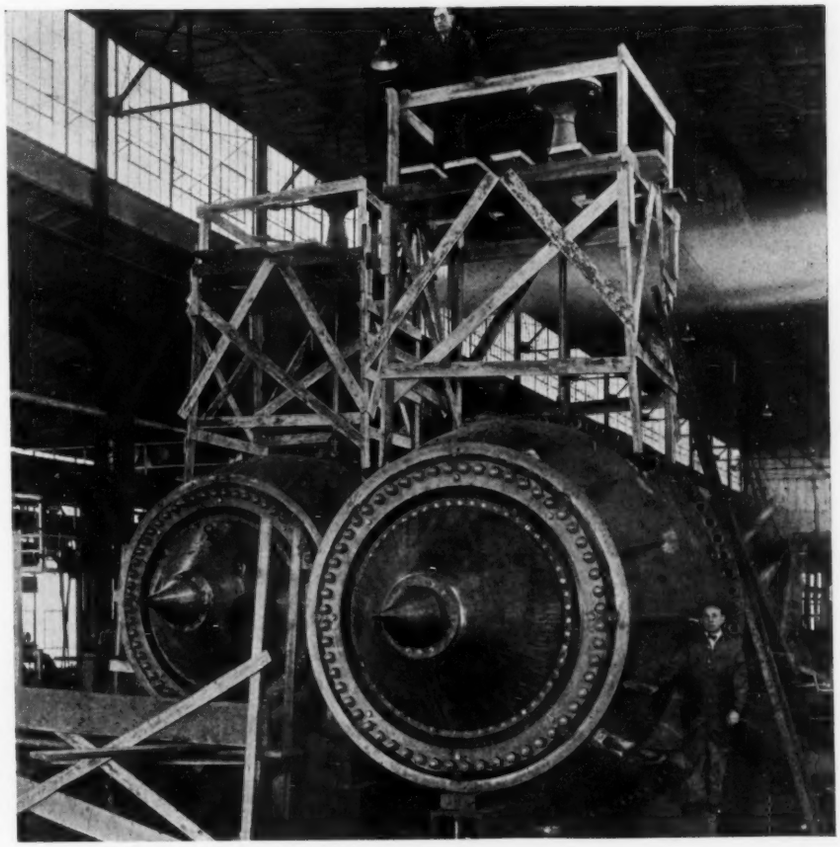


FIG. 10 TWO 84-IN. NEEDLE VALVES

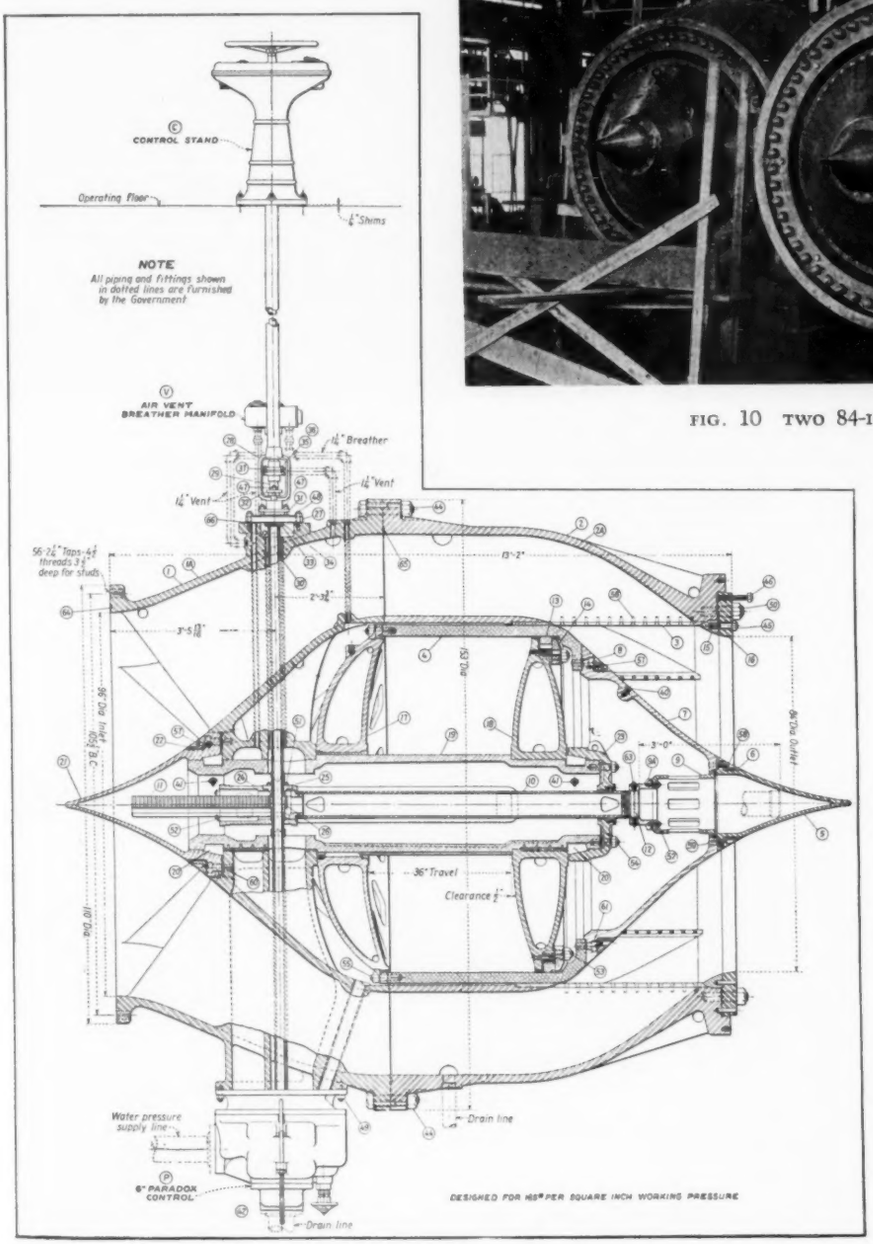


FIG. 9 VERTICAL SECTIONAL ASSEMBLY THROUGH THE NEEDLE VALVE

When specifications No. 519 for the construction of Boulder dam power plant, and appurtenant works were prepared, the layouts included a total installation of forty 72-in. needle valves, eight of which were installed in the 50-ft diversion tunnels, sixteen in the canyon walls at elevation 820, and the remaining sixteen still higher in the canyon walls at elevation 945. Each of these valves was to have been protected by high-pressure emergency gates and the gates were to have been operated by high-pressure oil cylinders.

When detail designs on these gates were started, it became evident that the concentrated loadings from stems of the highest grade material obtainable—virtually the equivalent of small telephone poles in size—and stressed to their ultimate safe limits by loads well in excess of a million pounds would be transferred from the gate leaves to the stems or vice versa in a rather un-

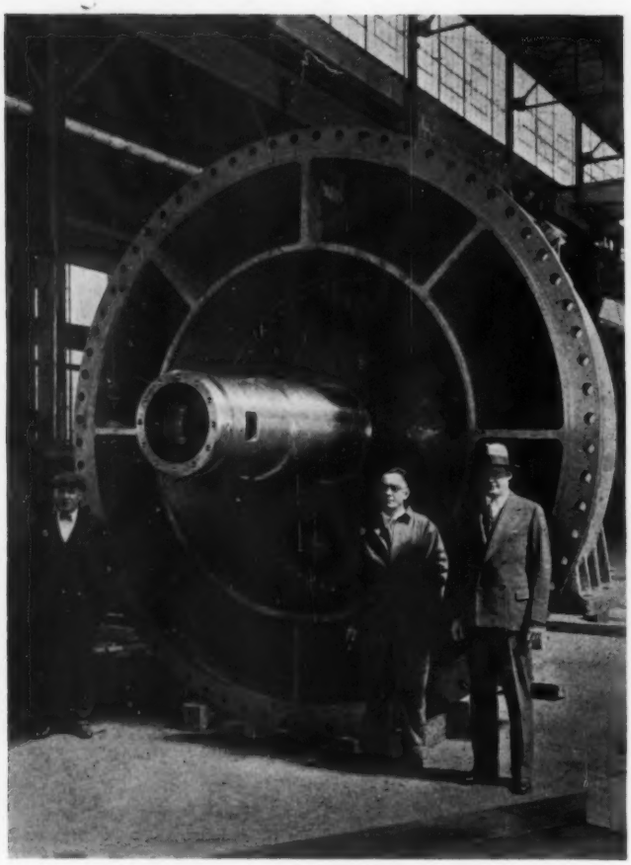


FIG. 11 84-IN. NEEDLE-VALVE NOZZLE CASING WITH NEEDLE IN PLACE AND BRONZE DIAPHRAGM TUBE, SHOWING ANNULAR PASSAGE AROUND THE NEEDLE SHEATH

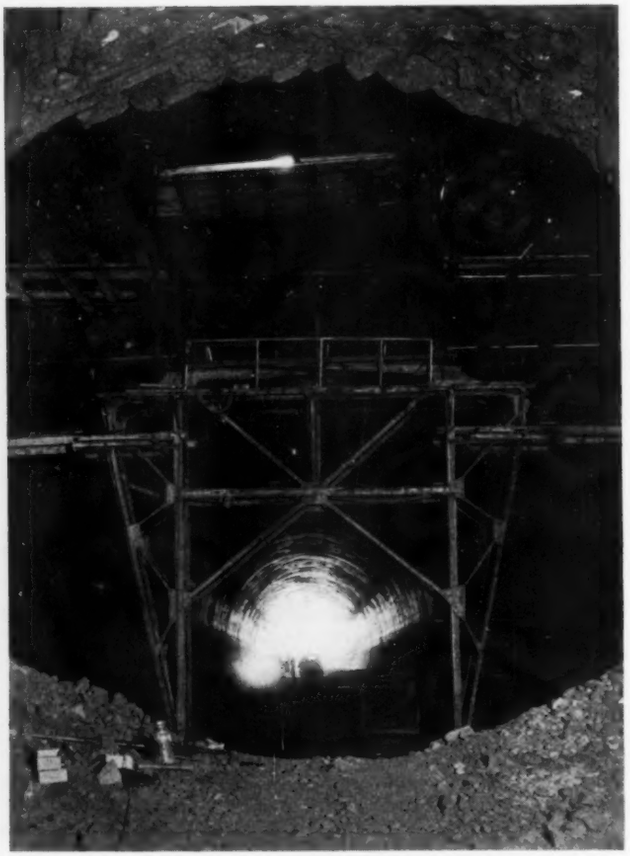


FIG. 13 INTERIOR OF DIVERSION TUNNEL NO. 2 WITH EXCAVATION PARTIALLY COMPLETED FOR TUNNEL-PLUG OUTLET WORKS ON THE NEVADA SIDE OF THE RIVER

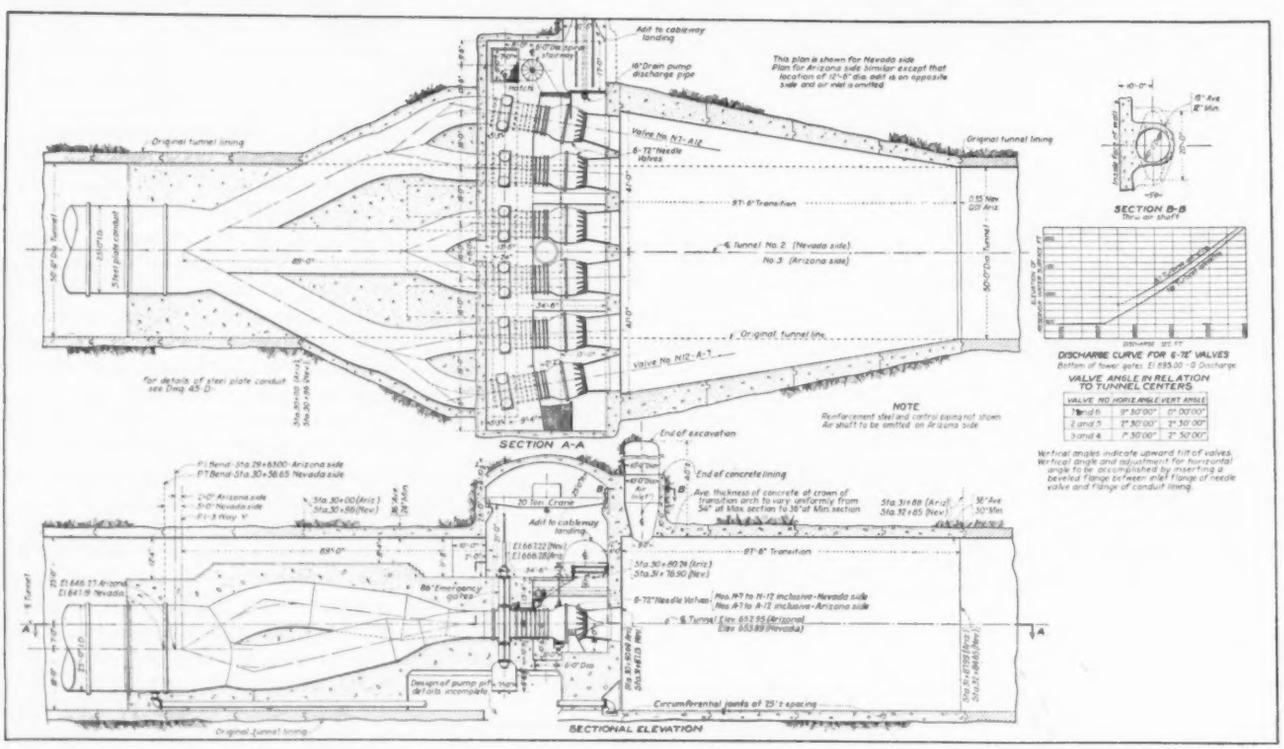


FIG. 12 SECTIONAL PLAN AND ELEVATION OF TUNNEL-PLUG OUTLET WORKS

satisfactory manner at best. This fact, coupled with the consequent localization of bearing contacts with their bronze seats, presented conditions approaching the zones of abrasive seizure so closely as to be of the most alarming nature. These and other factors accentuated the necessity of finding some other form of emergency-gate design.

In reviewing the designs for the high-pressure emergency gates, their fundamental weaknesses revealed the objectives which should be striven for in whatever new form of mechanism might be developed. Foremost among these was the desirability of moving the gate leaves into their opened or closed positions without exerting an enormous force in dragging the heavily loaded moving seat faces over the stationary seat faces with the probability of destroying the seats. Because of the exceptionally rapid velocity of flow through these gates during protracted periods of operation, it was likewise most desirable that the water passages through these gates should have the objectionable seat recesses removed from them, and that they should be practically unbroken and continuous with the conduits. The operating schedule for the tunnel-plug outlets made it desirable that the type of shut-off emergency gate chosen should be capable of remote control and closure from the central control pulpit in the power plant.

In reviewing all these limitations and desiderata it was discovered that by making the gate leaf with a circular ring extension below it, the recesses for the seats in the water passage could be filled in flush with the adjacent conduit on either side when the gate was in the wide-open position, thus converting the gate into what is known as the ring-follower type, which has been used successfully in many installations. This entailed nothing new but was an encouraging beginning. There still remained the more difficult task of eliminating the sliding contact between the moving and stationary bronze seat faces in opening and closing.

By providing an endless vertical belt of rollers on each side of the gate leaf the leaf could be raised and lowered readily. However, when it was lowered it would not be watertight. Here the idea embodied in the final design first began to take form. It was now seen that if the leaf were first lowered so as to register substantially in horizontal alignment with the stationary seats around the circular water passage, and then if it were allowed to move horizontally in the direction of stream flow by the slight amount necessary to allow its seats to come into contact with the stationary seats, the static pressure on its upstream side would force the movable seats into firm contact with the stationary seats and insure the watertightness of the gate. At the same time the necessity of sliding these surfaces upon each other

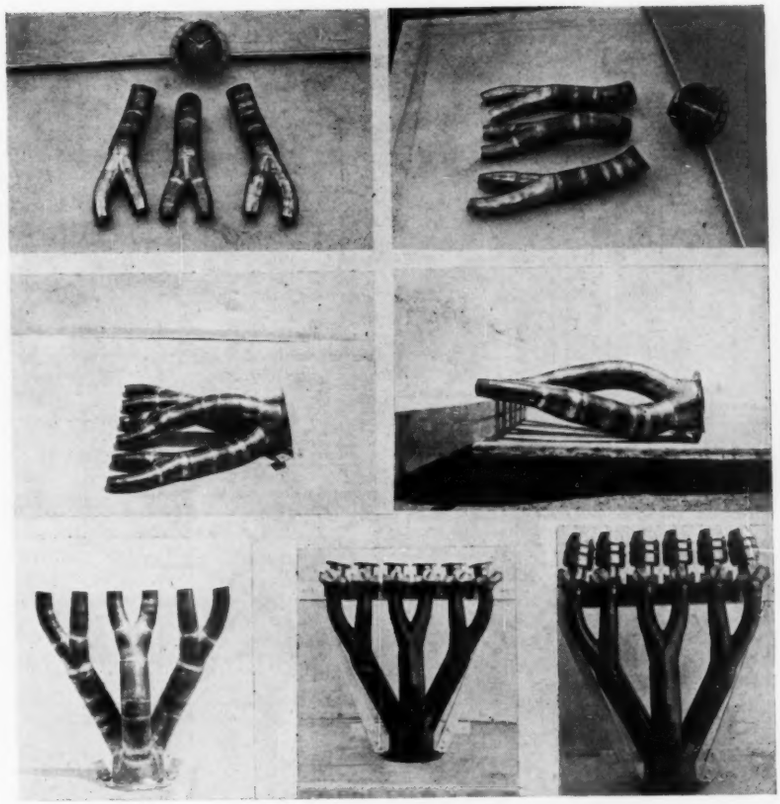


FIG. 14 PROGRESSIVE STEPS IN THE PREPARATION AND ASSEMBLY OF THE OUTLET HEADER THREE-WAY WYE MODEL WITH BRANCHES, WYES, EMERGENCY GATES, AND NEEDLE VALVES (SCALE 1:60)

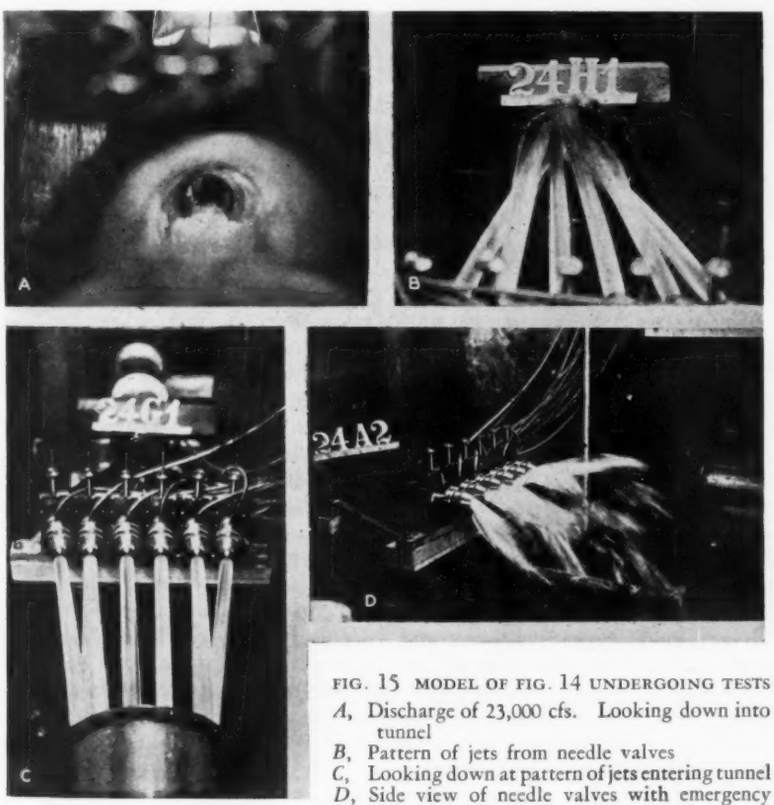


FIG. 15 MODEL OF FIG. 14 UNDERGOING TESTS

A, Discharge of 23,000 cfs. Looking down into tunnel

B, Pattern of jets from needle valves

C, Looking down at pattern of jets entering tunnel

D, Side view of needle valves with emergency gates partially closed, showing surging

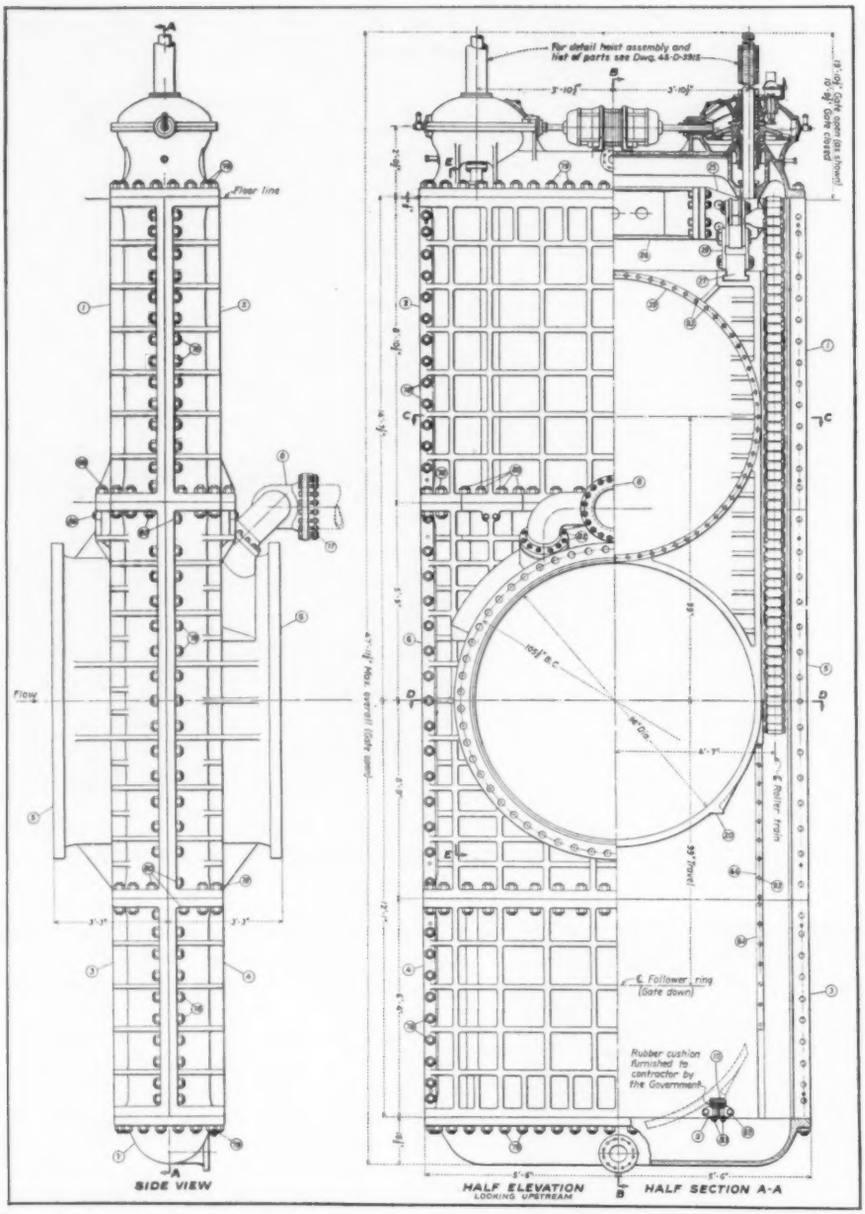

For detail hoist assembly and list of parts see Dwg. 46-D-3915
Floor line
Flow
SIDE VIEW
HALF ELEVATION
LOOKING UPSTREAM
HALF SECTION A-A
℄ Follower ring (Gate down)
Rubber cushion furnished by contractor by the Government.

FIG. 16 SIDE ELEVATION, HALF FRONT ELEVATION, AND A HALF TRANSVERSE SECTION OF THE 98-IN. PARADOX EMERGENCY GATE AND HOISTING MECHANISM COMPLETELY ASSEMBLED

to obtain seating contact would be avoided. It was also evident that the gate could be opened by a reversal of these actions.

After trying many promising systems of toggles, cams, and other devices with negative results, the problem was finally solved by interposing a supplemental roller train on each side of the gate. This received the static water load on the upstream face of the leaf and transferred it to the carriage mounting of the endless roller trains. By mounting these supplemental roller trains on inclined planes formed by parallel surfaces on the downstream side of the gate and in the endless-roller-train carriages, the gate would then be lowered on its roller-train carriages until it registered with the stationary seats in the closed position. Having traveled downward until it reached that position, it would engage stops which would prevent further downward travel, whereupon the roller-train carriages on either side of the now stationary gate leaf would continue their descent, causing the inclined roller trains supporting the gate leaf against the horizontal water load to roll down their inclined planes away from the leaf and so allow the leaf to be moved horizontally downstream by the water pressure on its upstream side into closing contact with the stationary seats.

Expressing this in another way, the vertical gate leaf is supported and restrained from horizontal movement in a downstream direction by inclined surfaces formed along its edges on either side on its downstream face. These surfaces rest upon and are carried by a series of rollers extending throughout the full height of the gate leaf. These two wedge roller trains in turn rest upon and are supported by a similar inclined plane formed within each roller-train carriage. The arrangement is such that if the gate leaf is held against downward travel and the roller-train carriages are permitted to travel downward, the wedge roller trains recede downstream out of contact with the inclined wedge surfaces on the leaf. If there is water pressure upon the upstream side of the leaf, that pressure will force the gate to move horizontally downstream and maintain it in contact with the wedge roller trains as they continue to recede until the bronze seats on its downstream face come into contact with the seats in the gate frame. This will prevent further downstream movement of the leaf and these seats will then be watertight. It is evident that with this arrangement there will be no sliding movement between the stationary and moving seats. A reversal of these movements opens the gates also without sliding contact between the seats.

Inasmuch as the design adopted provided a slide gate with the "slide" taken out, it was christened the "Paradox" gate.

As the detail designs for these gates were developed, it appeared that there was a lack of authentic data as to load-carrying capacity of rollers made from noncorrodible metals. A series of elaborate and painstaking tests was run upon various stainless steels when used as rollers and as roller tracks. In these tests the Bureau had the cordial cooperation of the Republic Steel Co. and the Crucible Steel Co. and their representatives. These companies furnished completely machine rollers and tracks of varying sizes, and material for making other rollers in the Bureau's machine shop in the basement of the Customs Building in Denver. Many tests were run with these rollers and roller tracks, the loads being applied by the Bureau's 4,000,000-lb testing machine in the Customs House in Denver, and very valuable data were developed which quite definitely established the practicability of the roller-train design adopted.

The side view of Fig. 16 shows one of these 96-in. Paradox emergency gates completely assembled. The companion view

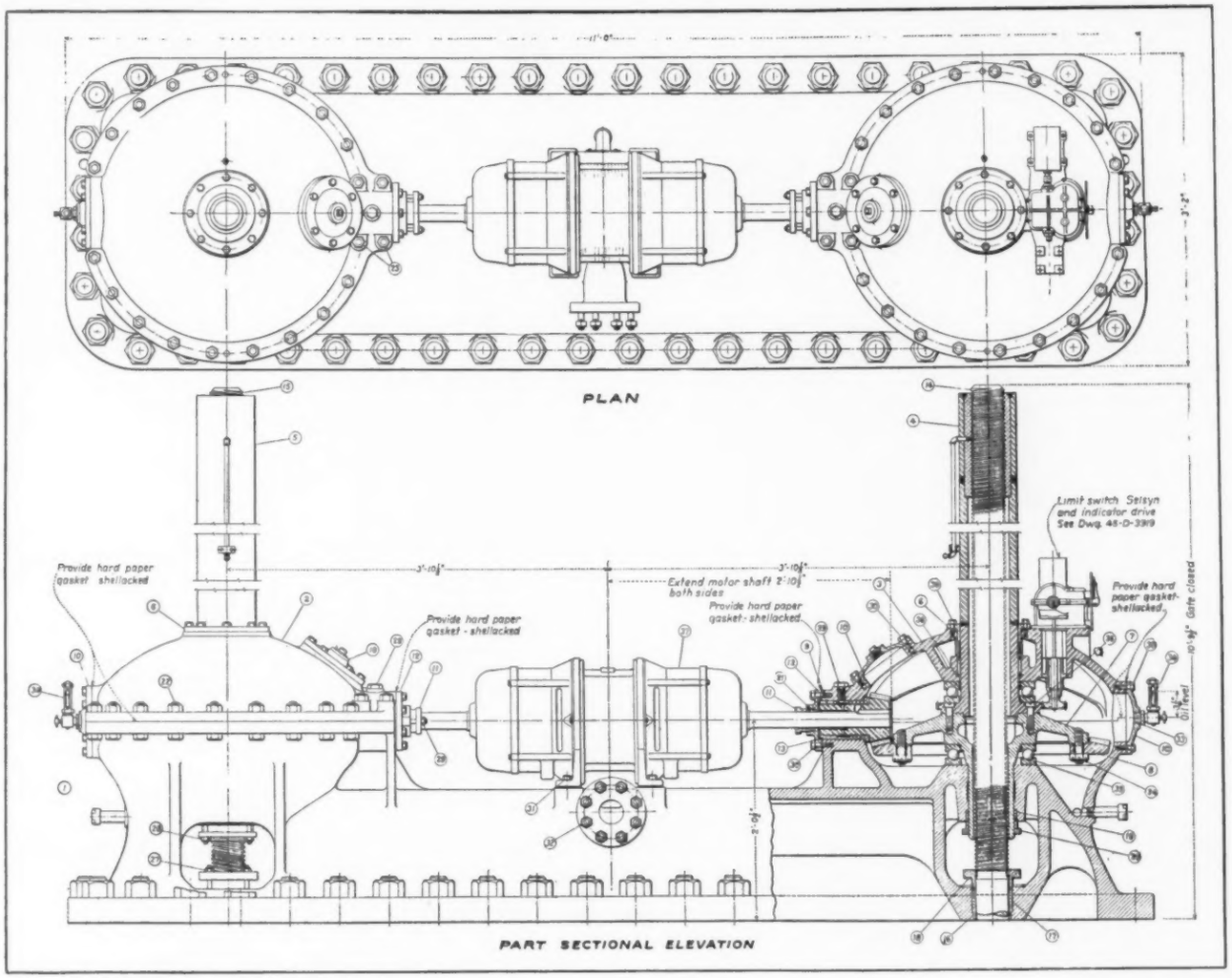

PLAN
PART SECTIONAL ELEVATION
Limit switch Selsyn and indicator drive See Dwg. 48-D-3319
Provide hard paper gasket shellacked
Provide hard paper gasket - shellacked
Extend motor shaft 2'-10½" both sides
Provide hard paper gasket - shellacked
Provide hard paper gasket - shellacked
3'-10½"
3'-10½"
2'-0½"
10'-9" Gate closed

FIG. 17 PLAN VIEW, HALF SIDE ELEVATION, AND HALF SECTION OF THE HOISTING MECHANISM OF 96-IN. PARADOX EMERGENCY GATE

shows a half elevation looking upstream through the conduit and a half-sectional elevation with the upper bonnet, gate frame, lower bonnet, and lower-bonnet cover removed to disclose the gate leaf and one of the two endless roller trains, the lifting beam above the gate leaf which connects the two roller carriages, the double toggle connecting the lifting beam to the gate leaf, and the inner construction of one of the twin hoist heads.

In Fig. 16 it will be seen that the hoisting mechanism is built into the upper-bonnet cover, near the opposite ends of which are two bowl-like extensions concentric with the vertical stems which pass through two stuffing boxes. The lower of these stuffing boxes prevents water from within the bonnet from leaking upward around the stem, while the upper prevents the oil in the gear case above from leaking downward around the stem. Each bowl is provided with a dome-shaped oil-tight cover.

Midway between the two gear cases a special double-ended $7\frac{1}{2}$-hp geared motor is mounted upon finished pads on the bonnet cover. The slow-speed shafts of this motor pass through oil-tight stuffing boxes in the gear cases and each drives a bevel pinion meshing with a bevel gear to which a vertical tubular member is bolted. (See Fig. 17.) To the upper ends of each of these tubes are secured the threaded bronze stem nuts within which run the threaded stems.

In Fig. 18 is shown a longitudinal vertical section *B-B* on the centerline of the gate with the leaf in the open position. Section *D-D* is a horizontal longitudinal section on the centerline of the conduit. These two views show how the water passage through the gate is maintained in practically unbroken continuity. Section *C-C* is taken horizontally through the upper gate bonnet and shows the typical "barrel-vault" cross-section through the gate leaf with its wedge rollers on either side and also its two sets of endless roller trains. Detail *G* is an enlarged sectional view taken at *G* of section *C-C* to show the construction of the cantilever ledge along the side of the gate leaf.

This heavy I-beam section of the roller-train carriage serves here in a most interesting way the dual purpose of load transmission from the wedge rollers to the rollers resting upon the gate frame and also to allow practically uniform load distribution across the entire face length of the heavily loaded rollers. The first mentioned of these dual functions is obviously accomplished by direct compression transmitted through the stem of the I-beam. The last-named function is not so obvious, and when it was first employed by the author to permit equalized loadings across the faces of the rollers in the roller trains of the north spillway regulating gate at Guernsey dam, it was seriously questioned and, in fact, declared impracticable by some.

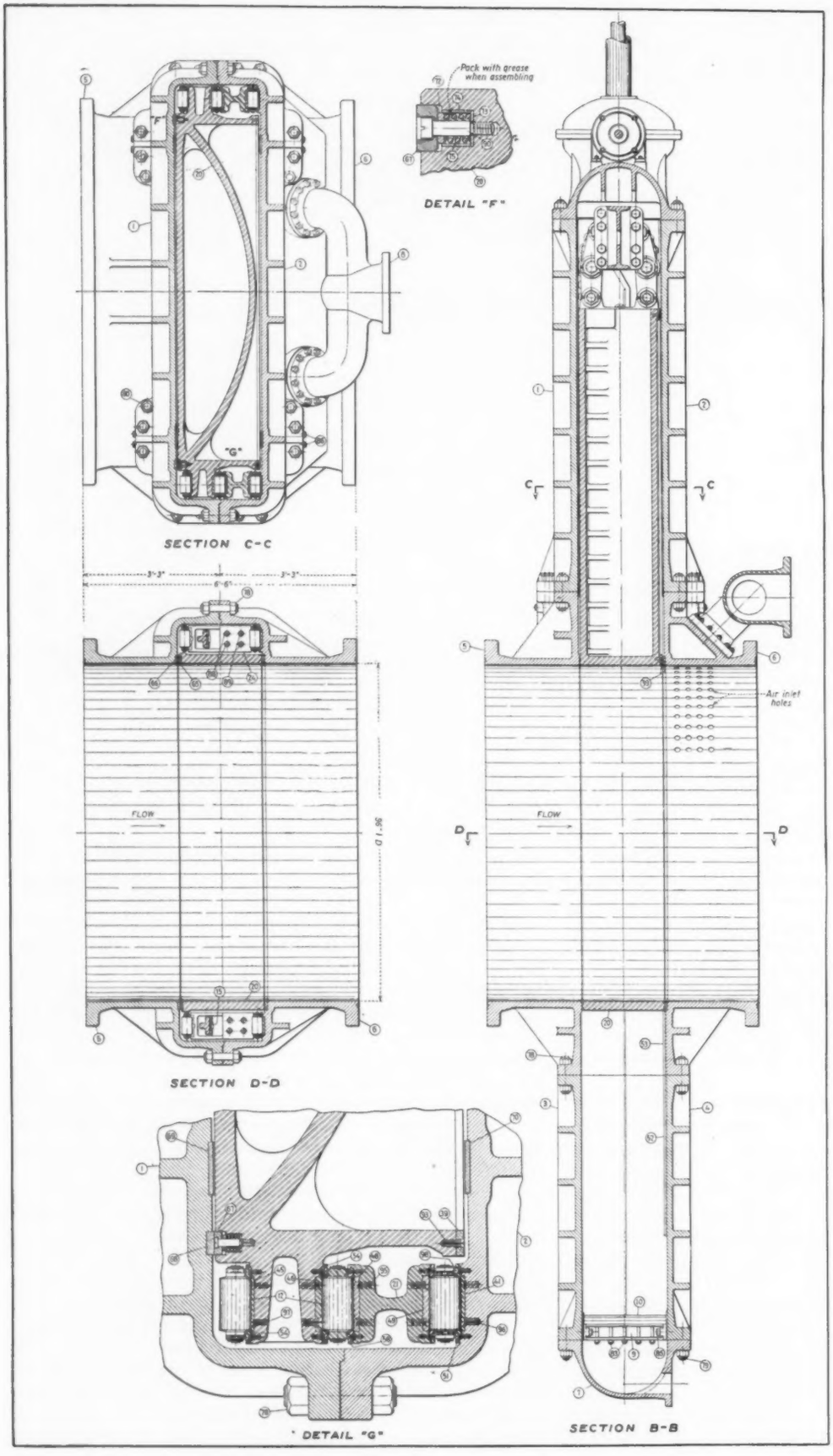


FIG. 18 DETAIL SECTIONAL ASSEMBLIES OF PARADOX EMERGENCY GATE

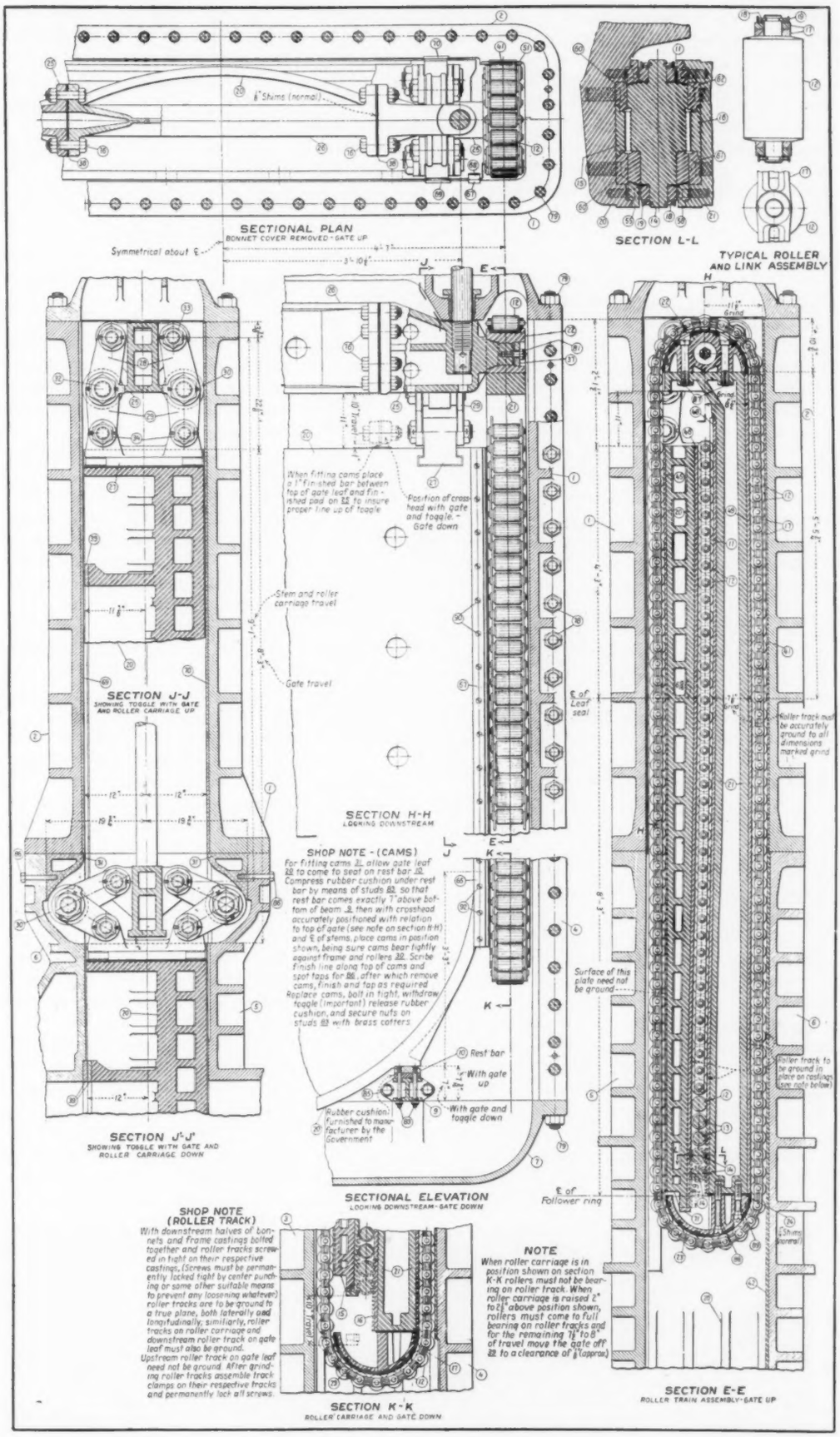


FIG. 19 ROLLER TRAINS AND TOGGLE ASSEMBLIES IN OPEN AND CLOSED POSITIONS

The principle is used on account of the distortion and relative displacement that takes place in iron and steel when employed in large structures. With gates of the size here used the heavy loads to which they are subjected will necessarily bend and deform them so that they no longer retain the true, flat, machined surfaces. Instead they are bowed and distorted and in consequence, under normal conditions, cause the cantilever shelf extensions along their sides to concentrate the heavy water load upon the end faces of the wedge rollers adjacent to the gate leaf. This concentration of loading would cause progressive failure of the wedge rollers and of the roller-train rollers as well. It is here that the stem of the I-beam makes these mechanisms possible, for while it has sufficient cross-sectional area when acting as a column under compression to transmit the wedge-roller loads across to the roller-train rollers, it likewise has sufficient flexibility to allow the roller tracks carried upon its opposite flanges to deflect in unison with the gate leaves and consequently distribute the loads evenly across their faces.

In Fig. 19 the vertical section *J-J* shows the positions of the twin toggles when extended with the gate up, while below section *J'-J'* shows the gate in the closed position with the toggles collapsed to permit the 10 in. of continued downward travel of the roller trains and carriage so that the seating action of the wedge-roller trains will occur.

Section *E-E* of this figure shows the complete roller train and carriage when the gate is raised and in the open position with the wedge-roller train in place. Section K-K shows the lower end portion of the roller carriage and roller trains with the gate down and in the closed position. By comparing this with the similar portions shown in section *E-E*, the shift in relative positions of the respective parts will be easily understood.

In the view marked "sectional elevation" one of the stop lugs on the bottom portion of the follower ring is shown resting upon the bar which prevents the leaf from descending beyond its closed position.

Section *L-L* shows the construction of the synchronizing pinions upon the lower ends of the wedge-roller trains whereby the correct relative positions of these parts are constantly maintained with respect to both the gate leaf and the roller carriages, as these parts shift their relative positions with respect to each other during the final portion of the closing cycle and the first portion of the opening cycle. A typical roller and link assembly is also shown.

These gates were designed for a working pressure of 185 lb per sq in. The maximum load against the face of the gate leaf is 1,482,000 lb.

The gate leaf is the most important member in these gates with respect to load. It is a steel casting in which the maximum combined stresses are held under 12,000 lb per sq in. Primary stresses are held to less than 10,000 lb per sq in.

The gate frames and bonnets are made of semi-steel and are embedded in concrete reinforced to take the entire water loads. The flanges of these parts are made sufficiently heavy to prevent deflection and leakage between the bolts.

The maximum unit pressures between the gate seats and the frame seats when the gate is closed and the wedge rollers free is 1920 lb per sq in. Inasmuch as the seats never slide on one another when they are in contact, this high contact pressure is desirable to insure watertightness when the gate is closed.

The rollers are of stainless iron having a Brinell hardness number of 250. They are 3 in. in diameter with a face 5 in. long and are spaced on $3^3/_8$-in. centers. There are 30 rollers on each side of the gate leaf. The maximum load on the rollers occurs when the wedge rollers raise and move the leaf from its seating engagement with the seat in the gate frame. When this occurs the average load on the 60 rollers supporting the gate is 28,100 lb.

By actual test the rollers used in the gate started to yield under a load of 58,500 lb per roller so that a factor of safety of 2.08 is present under the worst conditions of operation.

The roller tracks have a Brinell hardness number of 300 and their working surfaces, as well as those of the rollers, are ground smooth.

Tests were run to establish the coefficient of rolling friction with river silt on the tracks. The highest value found was 0.005 with low loads, and 0.003 was found near the critical loading. Using the worst case (0.005) the force required to overcome rolling friction when raising the leaf from its seat is 9900 lb. After the gate leaf is lifted free from its seat and the leaf is starting upward, the force required to overcome rolling friction is 4950 lb.

The maximum load on the twin-screw hoist is 46,000 lb which gradually decreases as the leaf approaches the fully opened position until it becomes 40,000 lb. The hoisting capacity provided is 100,000 lb, which is theoretically 218 per cent in excess of requirements.

Government specifications No. 562 including complete detail drawings of the Paradox emergency gates and the needle valves for the canyon-wall outlet works were issued and award made to the low bidder, Hardie-Tynes Mfg. Co. of Birmingham, Ala. The fabrication of the equipment is now well advanced.

The maximum travel of the stems is 109 in. and the time required to raise or lower the leaf is 11.6 min.

The gates in the canyon-wall outlets will be manually controlled from within each valve house. Those in the tunnel-plug outlets will be arranged for remote emergency closure from the control pulpit in the power house. All other operations will be by direct manual control from within the tunnel-plug-valve houses.

Many of the features of the butterfly valves, needle valves, and Paradox emergency gates as described and illustrated herein are believed to be new and novel and patent applications have been filed covering these features.

In a later issue the 50 ft by 50 ft bulkhead gates and their hydraulic hoisting mechanisms with automatic leveling control equipment will be described.

LARGE TANKS *Under* EXTERNAL PRESSURE

Results of a Test for Deformation Under a Vacuum and a Comparison With Unfired Pressure Vessel Requirements

By W. J. HART[1]

POWER transformers make use of boiler-iron tanks, commonly cylindrical in shape. It is not unusual that, owing to their size, they be made in two or more cylindrical sections for transportation, to be assembled at their destination. Ordinarily, such tanks are called upon simply to withstand internal pressures resulting from the static head of the oil which they contain, plus, in some cases, an additional internal pressure of 5 lb per sq in. Occasionally, a transformer tank is required to sustain a vacuum. In such cases it is necessary to design the tank for pressures ranging from an internal pressure of 10 to 15 lb per sq in. to an internal vacuum of 14.7 lb per sq in.

In anticipation of an extension of the vacuum requirement to larger and larger transformer tanks, the author made an analysis of what would be likely to happen under such conditions to large tanks designed without additional bracing and without materially increasing the wall thickness. An opportunity for comparing the analysis with actual tests fortunately presented itself when a demand came for three large tanks which were required to withstand a vacuum.

This paper presents the method used in designing the tanks and records the results of thorough tests made to determine what displacements might be caused by the actual application of a vacuum. The tanks had an inside diameter of 116 in. and a height of 212 in. On account of the size and the limitations set by railway clearances, the tank was built in two sections of roughly equal height and these were bolted together by means of angle rings.

An internal pressure results in a tensile stress in the walls, and since the pressure does not exceed one atmosphere, the resulting tensile or hoop stress is very low. If the tank is subjected to an external pressure, the stress magnitude will remain the same but it will be compressive instead of tensile.

It is well known that a circular ring or tube or a cylindrical tank can collapse as a result of external pressure alone. If the flexural rigidity of the tank is insufficient, such a failure can occur at stresses far below the elastic limit of the material. The pressure at which the circular form becomes unstable and buckling occurs is known as the critical pressure.

There are two major classifications of tubes, short and long, and the method of calculating the stresses depends upon the ratio of the diameter of the tube to its length. Transformer tanks rarely exceed a tube ratio of 4 to 1, that is, a height four times the diameter, and therefore the tank may be properly classified as a short tube with fastened ends. In the case of such a tube, the fastened ends increase the stability and the critical pressure is greater than that given by the following equation for long tubes:

$$q_{cr} = \frac{Eh^3}{4(1-\mu^2)R^3} \quad \text{[197]}[2]$$

in which

q_{cr} = critical pressure, lb per sq in.
E = modulus of elasticity (28×10^6)
h = plate thickness, in.
μ = Poisson's ratio
R = mean tube radius, in.

This equation may be used as long as the corresponding compressive stress in the tube is less than the proportional limit of the material. However, it should be used only for round cooling tubes or for long small-diameter auxiliary tanks.

For the short tubes for the transformer problem, no comparable formula is available as in the case of the long tubes mentioned. Here, instead of a formula, empirical data in tabular form are given.

Table 1 gives the true value of the critical pressure as long as the corresponding compressive stress is below the proportional limit of the material. Pressures are calculated for $E = 28 \times 10^6$ lb per sq in.

TABLE 1 CRITICAL LATERAL PRESSURE[a] IN LB PER SQ IN. FOR STEEL TUBES

	Values of $100(h/R)$							
R/l	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2
0.0	0.50	4.0	13.5	32	62	108	170	260
0.1	2.6	14.2	41	94	175	240	330	440
0.2	5.3	30	84	185	300	450	670	940
0.3	7.9	45	130	260	450	720	1080	*1580
0.4	10.8	64	165	350	640	990	1400	2000
0.5	13.8	78	210	450	780	1200	1870	2700
1.0	28	...	...	...	...	...	...	...
2.0	60	...	...	...	...	...	...	...

[a] From "Strength of Materials," S. Timoshenko, p. 603.
R = outside radius, in. l = height of tank wall, in. h = thickness of tank wall, in.

This table of critical pressures will be used to ascertain what thickness of plate to use with a reasonable factor of safety. A plate thickness of $^1/_2$ in. was selected as being adequate for a complete vacuum and the resulting calculations are as follows:

Collecting all the values, we have

R = 58.5 in.
l = 210 in. (subtracting 2 in. for the cover flange and bottom)
h = 0.5 in.

[1] Mechanical Engineer, Sharon Works, Westinghouse Elec. & Mfg. Co., Sharon, Pa. Assoc-Mem. A.S.M.E.

[2] "Strength of Materials," by S. Timoshenko, Part II, Advanced Theory and Problems, p. 602.

Therefore

$$\frac{R}{l} = \frac{58.5}{210} = 0.278$$

and $100\,\frac{h}{R} = 100\,\frac{0.5}{58.5} = 0.855$.

By interpolating the values in Table 1, a critical pressure of 51.45 lb per sq in. is obtained. Then, assuming a complete vacuum, the factor of safety is 51.45/14.7 or 3.5.

The factor of safety may be varied to suit conditions. It must be remembered, however, that strains are developed in the tank during shipment and this results in a certain wall displacement that may affect the stability.

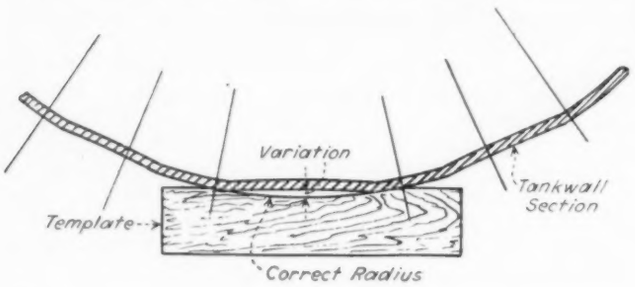


FIG. 1 TEMPLATE FOR MEASURING ECCENTRICITY OF CONTOUR

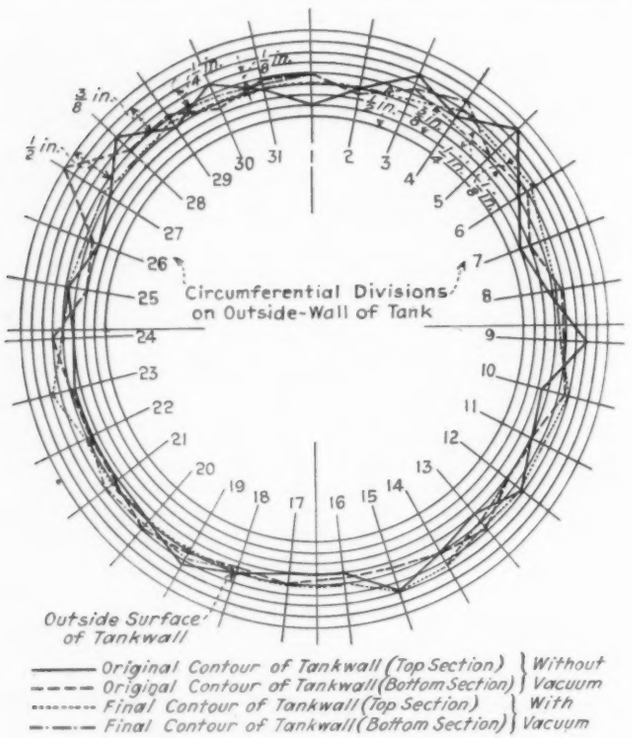

Circumferential Divisions on Outside-Wall of Tank
Outside Surface of Tankwall
Original Contour of Tankwall (Top Section)
Original Contour of Tankwall (Bottom Section)
Final Contour of Tankwall (Top Section)
Final Contour of Tankwall (Bottom Section)
Without Vacuum
With Vacuum

FIG. 2 CONTOUR OF TANK WALL BEFORE AND AFTER TESTING

Upon completion the tanks were tested for concentricity by means of a template, Fig. 1, made to the correct outside tank radius. The results of this test are shown graphically in Fig. 2.

It will be noted from Fig. 2 that the manufacturing irregularities were held to within plus or minus one-half an inch and this was considered to be good average shop practise. However, excessive flat and high lobes and eccentricity are recognized sources of failure in vacuum tanks. With this in mind, the flat and high lobes shown in Fig. 2 were indicated in chalk on the tank wall for observation when testing under vacuum to ascertain what effect they might have in causing displacement of the structure as a whole.

The following method was employed to measure the actual wall displacement:

The tank was graduated circumferentially in 12-in. increments at the top and bottom, each division being assigned a number for identification. Midway between flanges of the upper section of the tank, another circumferential line was established. Radial displacement measurements of the upper section were made on this line. A similar line was used on the lower section of the tank. Readings of displacement were taken with a structural-steel gage suspended from a boom at three points in elevation, at *A*, *B*, and *C*, and at each of the circumferential divisions. (See Fig. 3.) It was possible to obtain both the circumferential and the radial displacements by moving the gage from one division to the next.

Before applying any vacuum whatever, careful readings were taken at all the points mentioned and the results are recorded in Fig. 2. The tank was then evacuated in four stages in the following manner: A 7-in. vacuum was produced and held constant for half an hour, during which time all readings were taken and recorded. The same procedure was followed for vacuums of 14, 21, and 26½ in. It was not possible, on account of low barometer and losses in the system, to produce a vacuum higher than 26½ in. However, this constituted such a large percentage of a complete vacuum that it was considered a fair test. It will be noted in observing Fig. 2 that displacements encountered were very small indeed and for all practical purposes, they were negligible.

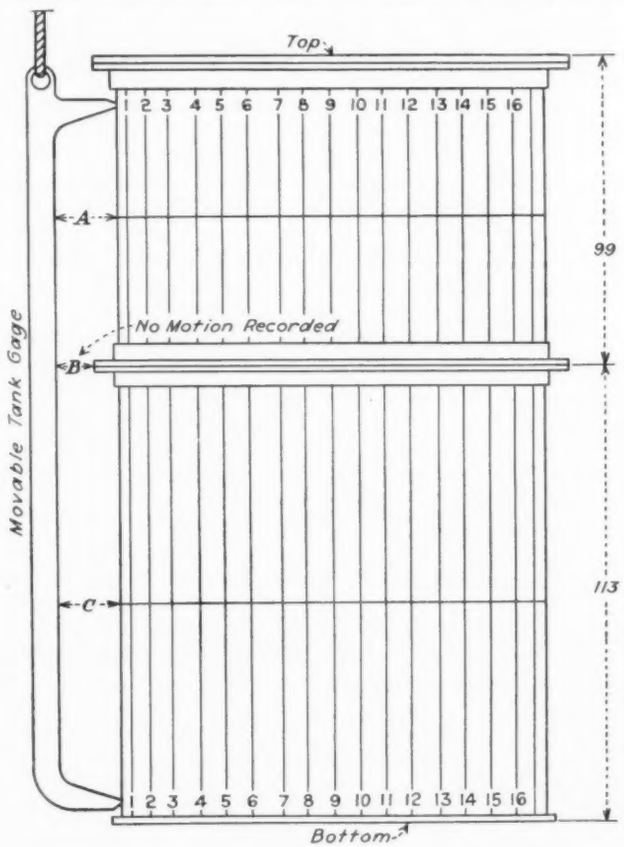


FIG. 3 METHOD OF MEASURING TANK DISPLACEMENTS

(Continued on page 630)

ELECTRIC WELDING *in* POWER-PLANT MAINTENANCE

By J. W. KECK[1]

IN THE past twenty years the development of autogenous or fusion welding by means of the electric arc or oxy-acetylene flame has placed welding in the position of being one of the most widely used tools of industry. During the first few years of the development of oxyacetylene and electric-arc welding, the percentage of failures was exceedingly high, with the result that fusion welding by either of these two methods was considered unreliable. Fusion welding was used principally as a means of making joints which would not be subjected to relatively high stresses and was accepted for use on jobs where failure of the weld would not involve serious consequences by endangering lives or damaging property. Subsequently, improvements were made in welding materials and equipment, with the result that welding became more widely used. While these improvements together with standardization of equipment and processes reduced the percentage of failures in welding, there yet remained considerable research and development which had to be carried on before welding attained the position of dependability that it now holds.

In recent years, improvement in welding technique and testing methods has been largely responsible for additional advances and refinements. Through the most rigid training of welders and intelligent control of all factors pertaining to welding procedure, it was found that the effect of the human element could be greatly reduced, resulting in a high standard of finished products. Hand in hand with improvement in welding technique have gone improved test methods. Numerous destructive tests have been devised which have contributed greatly in correcting or eliminating practises found to be detrimental to the strength and soundness of welds. Great progress has also been made in the field of non-destructive testing, particularly in the use of both X-ray and gamma-ray methods. By means of X-ray testing, it is now possible to examine welds in metal up to approximately six inches in thickness. With this assurance, large pressure vessels have been fabricated by the use of welding, and the strength and reliability of the finished products determined with a high degree of accuracy.

Fig. 1 shows a drum of a 17,440-sq ft boiler, for a working pressure of 400 lb per sq in., fabricated from four pieces of steel fusion-welded by the electric-arc process. There are two longitudinal and two circumferential welds. All nozzles are likewise welded in position.

Welding, owing to the nature of the process, has been used to the greatest extent in the machinery manufacturing industry. However, its usefulness has been extended

FIG. 1 AN ALL-WELDED BOILER DRUM

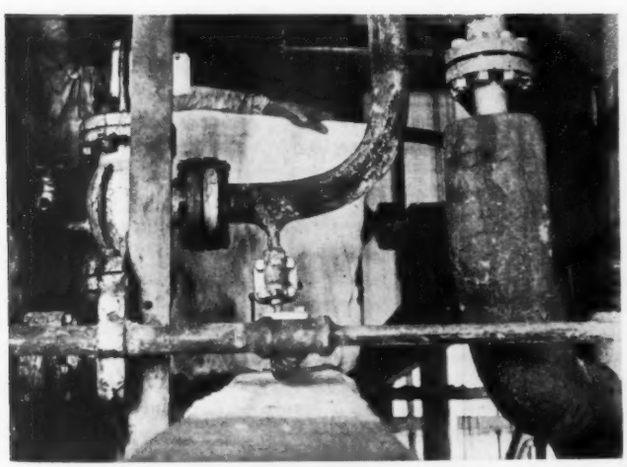


FIG. 2 DRAIN FOR A 400-LB STEAM LINE WELDED IN PLACE

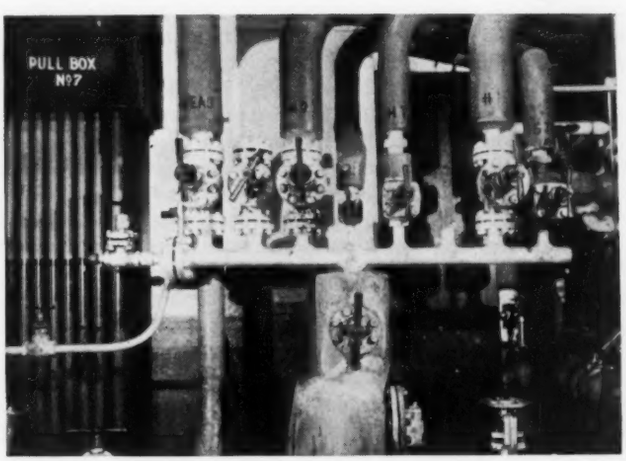


FIG. 3 ELECTRICALLY WELDED HIGH-PRESSURE DRIP MANIFOLD

[1] Division Plant Superintendent, Florida Power & Light Company, Dania, Fla.

Presented at a meeting of the Florida Section, December 28, 1933, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

FIG. 4 WELDED OIL LINES CONSTRUCTED OF RECLAIMED PIPE

FIG. 5 A WELDED CRANE STRUCTURE MADE OF SCRAP MATERIAL

until it is now employed in practically every field in which metals play an important part. While it is now possible under procedure control consistently to produce welds which are equally as strong or stronger than the parent metal, greater usefulness of welding will progress as additional improvements are made in nondestructive methods of testing.

POWER-PLANT MAINTENANCE

In the operation of generating stations, from time to time various leaks develop in piping, particularly in high-pressure lines subjected to wide variations in temperature. Maintenance of these lines by the conventional method of dismantling for repairs or renewal would, in most cases, result in lengthy outages of equipment and considerable expense. In the majority of instances such leaks have been effectively and permanently stopped by electric welding without dismantling the piping. Electric welding has also been used to advantage in installing supplementary piping without disturbing the original layout. An illustration of this is shown in Fig. 2, which is a drain in a 400-lb saturated-steam line. The component parts of this installation were fabricated in the shop and the connections at the steam line and drip header were made by electric welding.

Fig. 3 shows a high-pressure drip manifold built up by electric welding. This type of construction makes a normally complicated piping job a comparatively simple installation. An extension of this idea has often been utilized on large pipe lines at points where relatively small connections were required. A welded nozzle at the proper location and angle makes a quick and efficient job, at minimum expense.

Fig. 4 shows short sections of two oil lines constructed of reclaimed pipe and discarded boiler tubes. All joints and fittings in these lines were made up by electric welding. Since these lines were to be operated at comparatively low pressures, they were economically constructed of material which would have normally been disposed of as junk. In this particular installation, from the standpoint of appearance and maintenance, this type of construction has proved to be superior to lines of conventional fabrication.

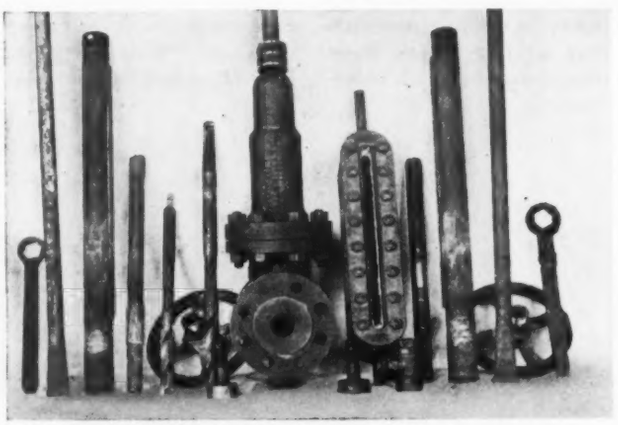


FIG. 6 TOOLS AND MISCELLANEOUS EQUIPMENT RECONDITIONED BY WELDING

Fig. 5 shows a crane structure for handling a fuel-oil unloading hose. This is another example of the use of electric welding to advantage in constructing serviceable equipment, utilizing scrap material. This structure was made at a cost considerably under that of other types of construction.

Fig. 6 shows an assortment of equipment and tools reconditioned by electric welding. Various pieces of expensive generating-station equipment and tools which formerly found their way to the scrap pile, as a result of wear and breakage, have been reconditioned by electric welding. Special tools or fixtures used in connection with often-repeated machine-tool operations have been quickly fabricated where ordinarily it required special castings. Expensive socket wrenches with worn internal faces or weakened shells have been built up to render as much service as new ones.

The ability to replace metal which has wasted away due to wear or corrosion is an important function of electric welding. Worn shafting and centrifugal-pump impellers have been rapidly and effectively built up with special welding rods, which replace yet vary little in composition or strength from the parent metal. Electric welding has also been used effectively in the maintenance of six steel barges used in transportation of fuel oil to generating stations. The barges referred to were 60 ft long, 20 ft wide, and 6 ft deep, with 7000 exposed $\frac{5}{8}$-in. rivet heads in each barge. These barges had experienced extremely severe service as a result of frequent docking, exposure to sea water, and heavy seas, with the result that the wasting of rivet heads and plates at the seams was encountered. Repairs were made by bead-welding the plates along the seams

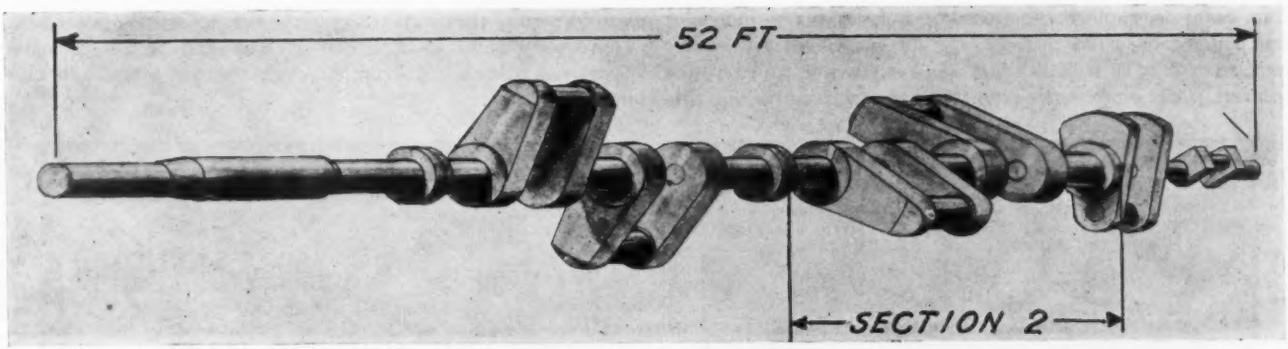


FIG. 7 A DIESEL-ENGINE CRANKSHAFT ON WHICH REPAIRS WERE MADE BY WELDING

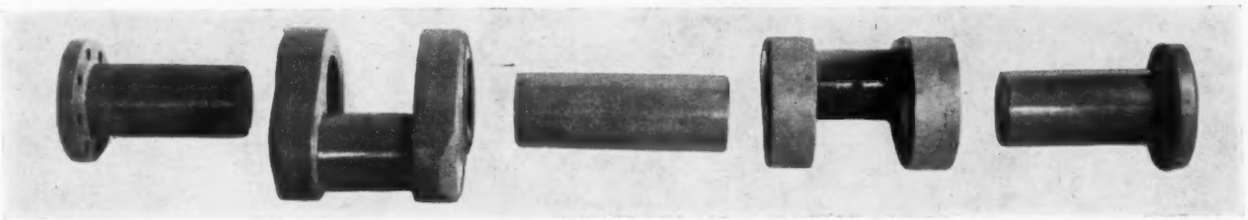


FIG. 8 CONSTRUCTION OF SECTION 2 THE CRANKSHAFT OF FIG. 7

and building up the rivet heads to their original size. The cost of repairs by this method represented only a small fraction of the expense which would have been incurred if the rivets had been renewed and the seams recalked.

In the maintenance of large Diesel engines, replacement of pistons due to worn ring grooves represents a major item of expense. In many cases this expenditure has been greatly reduced by utilizing a simple electric-welding process in rebuilding the groove lands as they become worn and machining the grooves to original dimensions, permitting the use of standard-size piston rings. Rebuilding of worn lands in the two-piece type pistons equipped with steel heads does not require preheating or a special welding process. It is important, however, that the head be thoroughly cleaned before the building up of lands is begun, as any carbon or dirt fused in the weld will result in difficulties in machining.

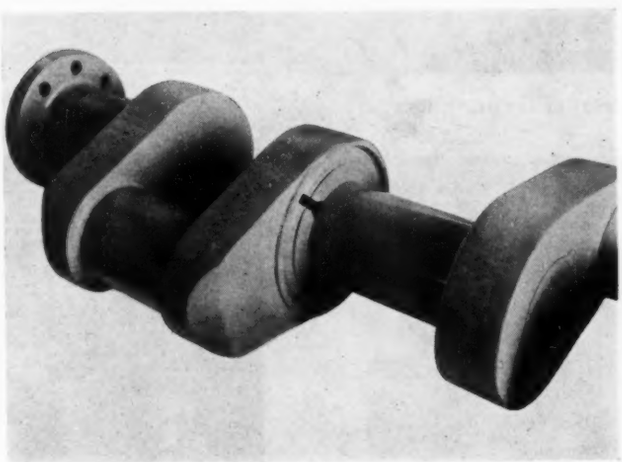


FIG. 9 THE WEB AFTER THE CRACK HAD BEEN CHIPPED OUT

REPAIR OF LARGE CRANKSHAFT

Up to this point, several applications of electric welding in generating-station maintenance have been referred to in a general manner without going into detail regarding procedure employed. It is felt that the methods and procedure employed in making permanent repairs to a fractured crank web of a large Diesel engine is of sufficient importance to justify a detailed description.

The repairs described were made to a built-up sectional type of crankshaft of a 2250-hp, two-cycle, four-cyclinder Diesel engine with a bore of 28 in. and a stroke of 44 in. Fig. 7 shows the general arrangement of the assembled crankshaft which was made up of four sections bolted together. The overall length of the shaft was 52 ft, and diameter of the journals 17 in.

Fig. 8 shows the construction details of section 2, which is made up of five forgings. Each forging was completely machined, then pressed in position and properly keyed to form the section.

Practically all large Diesel engines have a critical speed below their operating speed. Past experience has taught engineers that any variation in the amount of vibration or the speed position at which the critical normally occurs indicates that a change had taken place within the engine. Good operating practise demands that the cause of such variation be located before the unit is again placed in service.

This unit was shut down for its regular maintenance inspection and in passing through its critical speed the normal amount of vibration did not occur. The various parts of the engine were carefully examined and a hair-line crack was found in shaft section 2, power-cylinder crank web 1, on the generator side, starting from the keyway and extending outward for 6 in. This crack was so fine that it appeared to be only a scratch. In order to determine whether it was a scratch or a fracture, that area of the shaft was saturated with kerosene and wiped dry. A coating of chalk was then applied and the shaft caused to revolve. An oil stain appeared at the suspected line which indicated a fracture. Fig. 10 is a photograph of the oil stain through the chalk coating showing the location of the fracture.

In order to explore the fracture, a series of $^3/_8$-in. holes was drilled at various points along the crack. Measurements were secured at each drilling, making it possible to determine accurately the shape and extent of the fracture. From this information it was evident that repairs would be necessary before the engine could be operated with safety.

The manufacturer of the unit recommended that the shaft section containing the fracture be returned to the factory so that a new crank web could be installed. Removal of the shaft would require the dismantling of the engine, and the procedure, along with the cost of a new web, would be an expensive operation that would keep the engine out of service for two months.

FIG. 10 SHOWING THE CRACKED CRANKSHAFT WEB

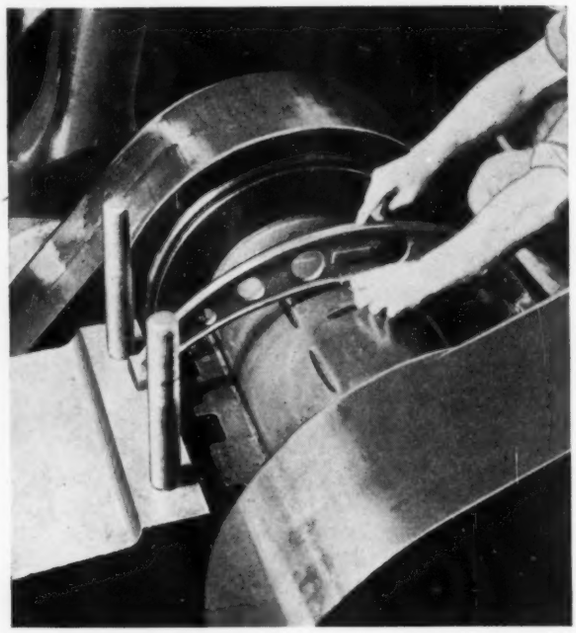


FIG. 11 BRIDGE GAGE IN POSITION FOR MAKING OBSERVATIONS

FIG. 12 DIAL INDICATOR IN POSITION FOR MAKING OBSERVATIONS

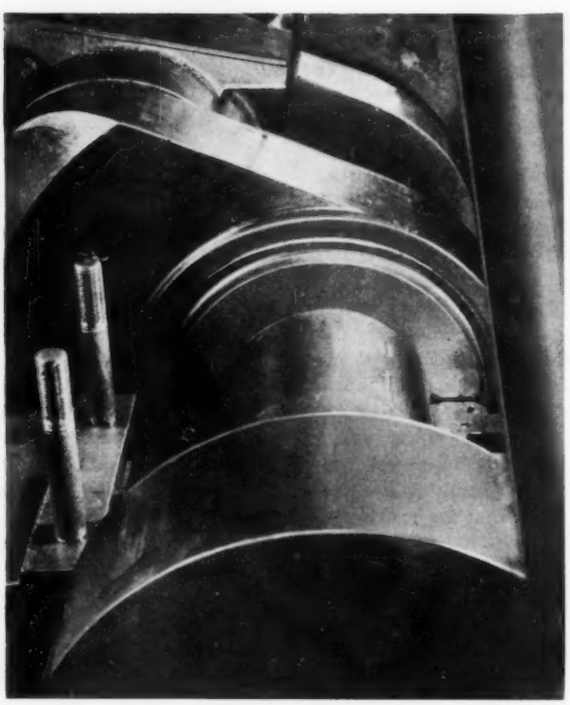
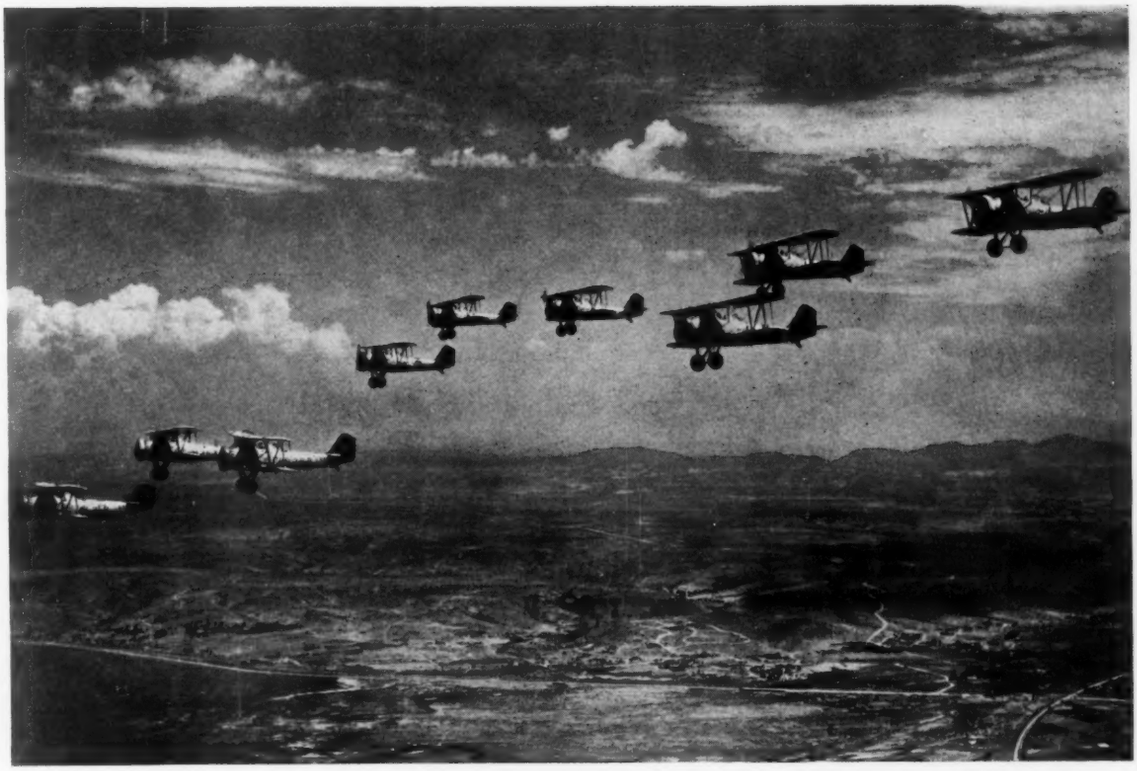


FIG. 13 THE WEB AFTER THE WELDING WAS COMPLETED

The feasibility of electric welding was considered and it was decided that repair by this method was possible, provided all of the metal surrounding the fracture be removed, the temperature of the web regulated in order to prevent it from

(*Continued on page 630*)



SCOUTING-PLANE FORMATION

Progress in

NAVAL AVIATION

By ERNEST J. KING[1]

DURING the past fiscal year, additional funds granted under the National Recovery Administration have permitted the Navy to maintain its one-thousand plane program, equip existing aircraft with modern navigational instruments and radio sets, and make other improvements in naval aircraft which have not been possible heretofore under annual appropriations.

AIRCRAFT CARRIERS

The Navy's fourth aircraft carrier *Ranger* was placed in commission in June, 1934. The *Ranger's* construction incorporates a high degree of modernization of design based on the Navy's extensive operating experience with the *Lexington* and *Saratoga*. Her preliminary operations have been pronounced a marked success.

Contracts have been let and work started on the *Yorktown* and *Enterprise*. These carriers will have displacements of 20,000 tons as against the *Ranger's* 13,800 tons. The construction of these two vessels will bring the Navy within 14,500 tons of the total aircraft-carrier tonnage allowed by treaty. The *Yorktown* is scheduled for commissioning in October, 1936, the *Enterprise* in February, 1937.

AIRSHIPS

No new airships have been constructed or placed in service in the past year. The U.S.S. *Macon* proceeded from Lakehurst to the new airship base at Sunnyvale, Calif., last October. From there she has operated successfully with the fleet in several maneuvers. Her longest period of continued operation away from her main base was in April and May when she took part in the maneuvers in the Caribbean, operating from a mooring-mast base at Miami. The ship encountered extremely rough air in crossing the mountains while en route from Sunnyvale to Miami.

Experiments with the use of fuel gas having approximately the same density as air are being carried out at Lakehurst in the non-rigid airship K-1. The experiments indicate that the range of airships may be very considerably increased by the use of fuel gas instead of gasoline.

[1] Rear Admiral, United States Navy, Chief of the Bureau of Aeronautics.

Illustrations are from official photographs of the U. S. Navy.

Contributed by the Aeronautics Division for presentation at the Annual Meeting, New York, N. Y., Dec. 3 to 7, 1934, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

ON THE U. S. NAVY ALASKA FLIGHT; MT. FAIRWEATHER IN BACKGROUND

The metalclad airship *ZMC-2* is now nearing the completion of her fifth year of continuous and successful service.

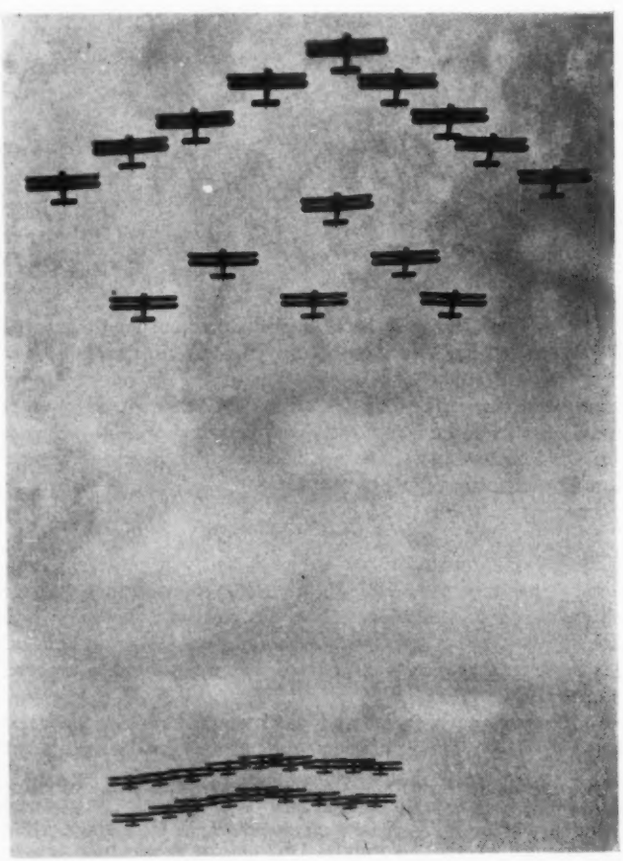
TRENDS IN DEVELOPMENT

The Navy reports gratifying progress in the production of new types of Naval airplanes. The general trend is toward increased speed, maneuverability, and range. Special attention has been given to the development of various flap and lift-increasing devices, of wing sections of improved characteristics, particularly low-moment coefficients, and to the improvement of retractable landing gears, cockpit enclosures, variable- (controllable-) pitch propellers, and radial-air-cooled-engine cowlings.

The Navy Department has continued to sponsor fundamental research in materials in cooperation with the National Advisory Committee for Aeronautics and the United States Bureau of Standards and also by direct purchase and test of new materials at the Naval Aircraft Factory, Philadelphia.

Stainless steel has been increasingly used on service series of airplanes by reason of its ability to withstand the severe corrosion induced by use in the tropics and proximity to salt water. It has been used for the manufacture of seaplane floats of stainless steel throughout, joined by spot welding. It is being used also in the construction of the framework of a lower wing for a flying boat. This metal is used without the addition of any protective coating.

By far the larger volume of materials used in present-day construction of aircraft for the Navy consists of high-strength aluminum alloys. Wing spars, wing ribs, monocoque and semi-monocoque fuselages, seaplane floats, and flying-boat hulls are designed for and constructed of aluminum alloy. Magnesium alloys, although comparatively new, undoubtedly have their applications. The Bureau of Aeronautics is sponsoring a manufacturing program of parts to be used in service tests with the expectation that much valuable information will be obtained as a result. Concurrently, with the use of light-metal alloys has gone an unceasing warfare against corrosion. Protective coatings are known which provide a reasonable degree of immunity from the effects of corrosion. It appears that the majority of the cases of corrosion in the aluminum alloys can be traced to improper heat treatment, a condition which can only be overcome by a careful regulation of shop processes. The Bureau maintains and revises specifica-

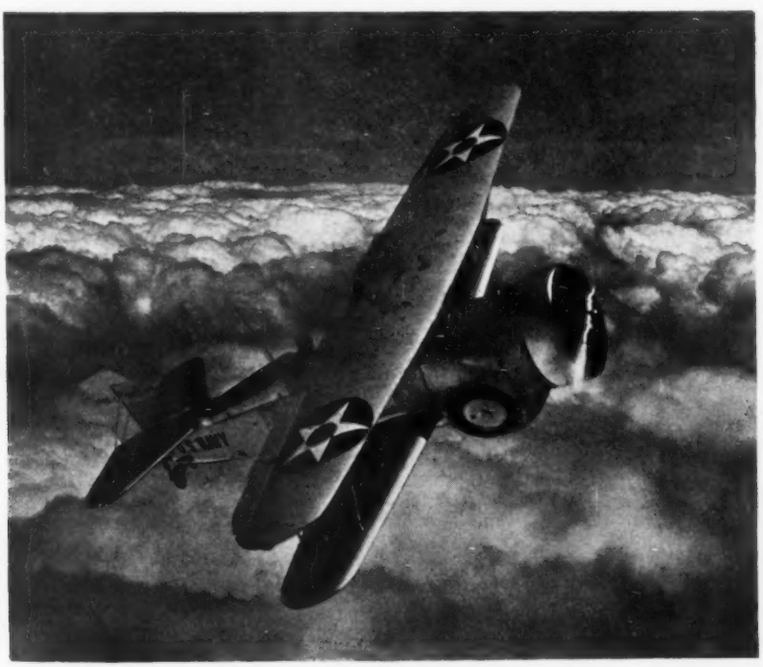


PLANES OF THE AIRCRAFT SQUADRONS PASSING IN REVIEW

U. S. NAVY PLANE IN FLIGHT

tions covering both shop methods and materials, a routine task which does not ordinarily strike one's attention but which is of a degree of importance equal to that of fundamental research.

Power-plant development continues to point toward higher supercharging, relative speeds, and brake mean effective pressures. Cooling difficulties attendant with higher horsepower ratings and supercharging have presented problems only overcome after considerable study and service usage. Two-row radial engines will soon be in service. Investigation and study of the Diesel aircraft engine is an important project.



U. S. NAVY BIPLANE

The necessity for a higher octane fuel is increasingly apparent Progress in commercial availability of aviation fuels of higher octane value suitable for service use and storage has not been as rapid as desirable.

A satisfactory advance has been made in the design and use of controllable-pitch propellers, the basis of several important improvements in airplane performance.

There has been a steady development in aircraft radio equipment. Attention has been focused on the refinement of detail, standardization, and elimination of conflicting types. The noise level in aircraft radio sets has been satisfactorily reduced through the introduction of more efficient shielding systems. Service airplanes are now completely shielded upon production.

The work on new instruments has resulted in an improved type of compass, electric tachometers, scouting- and fighting-plane plotting boards, navigational computers, and octants. Experimental installations of automatic pilots have been made to determine the suitability of this equipment for naval requirements.

Numerous service reports have been received during the past year describing the satisfactory functioning of safety devices. Self-inflating life vests and life rafts, fire extinguishers, safety belts, and parachutes are included under this heading. Attention is being directed more and more to high-altitude flying equipment, and it is safe to predict that important advances will be made in this field within the next two years. The efforts of manufacturers and designers are being encouraged to refine their products to afford satisfactory strength and at the same time to save weight. It is true that it is becoming more and more difficult to reduce weight, and the results of arduous labor can only be expressed in a saving of a few ounces instead of pounds; but a fraction of a pound, accumulative over a series of production airplanes, makes a considerable difference.

MECHANICAL ENGINEERING

Vol. 56 OCTOBER, 1934 No. 10

GEORGE A. STETSON, *Editor*

Power From Tropical Seas

IT IS A SOURCE of satisfaction to read in the daily press of attention-arresting developments on which MECHANICAL ENGINEERING can throw some light. A case in point is the recently publicized plan of Georges Claude to make ice off the coast of Brazil by means of his power plant that utilizes the energy made available by differences of temperature in tropical seas. In the December, 1930, issue of MECHANICAL ENGINEERING Professor Claude described the power plant installed at that time in Cuba and explained how it works. Engineers who wish to refresh their memories will find Professor Claude's article useful.

Machines Back of It

THE publishers of *Creative Design* have sent us a copy of the first number of this new quarterly devoted to the decorating and home-furnishing trade. In spite of the fact that engineering is creative and one of its principal functions is design, the magazine seemed to be beyond the scope of our own. But the slender wire helix which, instead of the usual stitching, holds together the binding edges of the pages of this new book must have an engineering history back of it. And engineers may take justifiable pride in noting that the beautiful fabrics and household equipment that are illustrated in this magazine are the product of the machines that some persons affect to despise and others assure us mean the doom of civilization. Without lacking in appreciation of individual ar stic creations, we may compliment the creators of these articles in utilizing so effectively the abundant possibilities of machinery.

The Stretchout Again

EMPHASIS that the leaders of the United Textile Workers have laid on the stretchout recalls the study of this important industrial problem reported by Elliot Dunlap Smith in his article "Lessons of the Stretchout" that appeared in the February, 1934, issue of MECHANICAL ENGINEERING. Readers who wish to refresh their minds on this problem will do well to reread what Professor Smith had to say. The wide variety of success and failure noted in the mills upon which the study was based indicates the importance of the management function in preparing for, installing, and operating changes brought about by technological advances. Just as was the case with Huck Finn when he painted Tom Sawyer's fence, the worker is responsive to the method by which these changes are introduced and operated. Workers, apparently, act like human beings, and, as Professor Smith says, "the human problems of methods change are greater than those of the introduction of labor-saving machinery." And further, "unless adequate provision is made to support technological advance by equivalent advance in other fields, especially in the management of human beings, such an advance is likely to bring serious human, as well as economic, consequences." Viewing the stretchout as a casus belli in the present textile strike, this would appear to be so.

The Fall Conferences

AS WAS the case last year, opportunity will be provided this fall for representatives of the A.S.M.E. local sections to come together in group conferences for the purpose of discussing Society affairs preparatory to the Annual Meeting in December. An announcement of the dates and locations of these conferences will be found on page 636 of this issue.

The last few years have been trying ones for everybody, and most individuals, organizations, and institutions have been subjected to self-analysis and critical evaluation. Out of this great good has come. The A.S.M.E. has benefited in this respect from the rigors of the times and has faced the situation realistically. Among other evidences may be cited the redefinition of objectives approved by the Council at its July meeting and published on page 572 of the September issue.

It is to be hoped that members of the Society have studied these objectives thoughtfully and that such study will stimulate a constructive discussion of fundamental Society policies, ideals, and program. In the recovery period that lies ahead the Council needs the assistance of every member and every group of members. Unless it knows what individuals and groups are thinking about the Council cannot perform its functions to the best advantage. Differences of opinion, if they arise, can and will be settled by cooperative action based on understanding, but the stimulating effects of new and constructive ideas are needed to keep institutions alive and put punch into their programs. Members and local sections have an opportunity to express themselves fully at the fall conferences, and may be assured that the ideas brought to the attention of the Council by the representatives from these conferences will be gratefully received and carefully considered.

Qualifications for Society Membership

MEMBERS of The American Society of Mechanical Engineers will soon have an opportunity to discuss proposed changes in the Constitution of the Society that will affect the grades of membership and the requirement of admission to those grades. As stated in the report of Council actions in the August, 1934, issue

of MECHANICAL ENGINEERING, page 510, the proposed changes are the recommendation of the Committee on Policies and Budget and are based on suggestions in the first annual report of Engineers' Council for Professional Development.

The purpose of the proposed changes is to enhance the prestige of the various grades of membership by stiffening the requirements and by adopting such specifications as will make the grade designations more nearly uniform with those of sister engineering societies in which the E.C.P.D.'s suggestions are also being considered. With the minimum requirements for membership in the student, junior, and member grades defined, greater significance will be attached to every grade. The result should be a raising of membership standards in general, and this should add so greatly to their value and prestige as to build up a stronger and more influential society.

As long as membership in any organization requires the recommendation of persons already members, as is the case of the A.S.M.E., the members themselves have opportunities to see to it that men of proper caliber are elected. They also are under obligation, when their names are listed by the applicant for reference, to safeguard the interests of the Society, and not let considerations other than those which should apply in such cases or enthusiasm for large numbers warp their judgment of the applicant's qualifications. No good purpose is served by the election of unqualified and indifferent members. On the other hand, the man the Society needs and would be proud to have on its rolls will esteem membership more highly if convinced that the qualifications he is required to meet are sufficiently strict to demand his respect.

Engineering Employment

IN MECHANICAL ENGINEERING and elsewhere to an increasing extent it is being contended that employment in general and engineering employment in particular wait upon the recovery of the durable-goods industries. Because of this the A.S.M.E. Council, a year ago, appointed a special committee on the capital-goods industries to concern itself with their problems and to suggest what Council might do to assist in the recovery of these industries whose prosperity means so much to the engineer. This committee reported last December the results of a survey it had made in a number of cities in different parts of the country. The report was published in the February, 1934, issue of MECHANICAL ENGINEERING.

In June a resolution from the A.S.M.E. local sections' delegates meeting at Denver, Colo., relating to conditions of engineering employment was transmitted to the Council and was referred by the Council to this special committee. Under the title "Durable Goods and Engineering Employment," the report of the committee is published as the leading article of this month's issue.

To those who expected that this committee or any other could find a solution to the unemployment problem in the engineering profession, the report will be a disappointment. It reviews what the Administration has done to effect recovery and shows how inadequately the results have been in so far as engineers are concerned. It emphasizes the need for confidence upon which any real recovery must feed and shows why this confidence is weak.

One feature which is worthy of comment and emphasis is the advice to those who face the discouragement of trying to find employment to reassess themselves in terms of the functions they are competent to perform rather than the jobs they have held. To some this may reveal hitherto unimagined possibilities, and it may save others from a fruitless search for a type of job that the depression, technological advance, and other changes may have made obsolete.

Obviously engineering societies are not organized as employment bureaus although they have supported the Engineering Societies Employment Service as a joint enterprise for many years. The untiring and unselfish devotion of the staff of this organization, measured in terms of human values, is one of the bright spots of the depression. Financial support of this agency has been increased during these trying years as conditions unquestionably indicated. Relief organizations, sponsored by local engineering groups, have given admirable service in many localities. The American Engineering Council, through its executive offices in Washington, has served in a liaison capacity between the engineering societies and their members on the one hand and the Government departments and bureaus seeking the services of engineers on the other. The only reasons that the work done by all of these agencies is not more generally appreciated is because the demand for jobs and relief is so great that what has been accomplished seems small in comparison.

At the expense of appearing to be trite, it must be emphasized that relief and employment are individual and local matters. With central agencies overtaxed yet striving to do all they can, it is unwise for engineers not to organize locally for relief and recovery during the coming winter and redouble their efforts to handle their own affairs as thoroughly and as competently as possible. Such local organizations will make more effective whatever the Council and other groups may be able to do.

Postscript

AT ITS meeting of September 19, which will be reported in the November issue, the Executive Committee of the A.S.M.E. Council accepted in principle the recommendations of its committee on the capital-goods industries and took steps to determine procedures for their execution. The Executive Committee also voted to prepare a pamphlet designed to assist engineers in finding employment. It is expected that the pamphlet will be preprinted in MECHANICAL ENGINEERING and be available in reprint form for wide distribution. It should be of practical benefit to men faced with the perplexing and vital problem of relocating themselves in profitable employment. These actions of the Council mark very concrete steps in a program of service to A.S.M.E. members and the engineering profession.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

COMBUSTION TRIANGLE AND SOOT FORMATION

IN 1920 W. Ostwald introduced a graphical process for the estimation of analyses of exhaust gases. This process makes it possible, by plotting the values of carbon dioxide and oxygen in the exhaust gases obtained by the Orsat apparatus, to determine rapidly from the so-called combustion triangle thus obtained the degree of completeness of combustion and the amount of excess air present. Where the combustion has not been complete the Ostwald combustion triangle shows a certain amount of carbon monoxide in the exhaust gases.

Hitherto it has been assumed in plotting this triangle that the elementary hydrogen content in the fuel has been completely consumed but that only part of the carbon has burned to carbon dioxide and the remainder converted into carbon monoxide.

The use of the combustion triangle has received a blow lately in that it has been recognized that the assumption dealing with incomplete combustion is not correct. The combustion of most fuels produces, in addition to carbon dioxide, considerable amounts of water vapor, so that, in accordance with the laws of chemical equilibrium, hydrogen must be present in exhaust gases as well as oxide of carbon. As a rule, in the determination of heat losses through incomplete combustion the presence of hydrogen should not be neglected. In the dry exhaust gases of Diesel engines the Ostwald combustion triangle shows not infrequently one or more per cent of carbon-monoxide content. This degree of incompleteness of combustion indicates, when properly determined in accordance with the chemical equilibrium, volume contents of carbon dioxide and hydrogen which can be determined without any trouble by gas analysis.

In actual practise it has been found that where combustion takes place with an excess of air, neither carbon monoxide nor hydrogen appear in the exhaust gases in material quantities. It has been generally observed that in such a case the conditions and processes which cause the incomplete combustion favor the formation of soot much more than carbon monoxide. As an authority for this statement the author quotes the thesis presented to the Munich Technical University in 1932 by F. von der Nahmer.

In the engineering literature there are many statements to the effect that even where the excess of air present is small, refined methods of measurement do not show the presence of carbon monoxide in exhaust gases from engines and furnaces. The Ostwald combustion triangle, however, usually shows that carbon monoxide must be present in exhaust gases, which is taken as a proof of incompleteness of combustion. Whereas the results of gas analysis are negative, traces of carbon monoxide and consequently of hydrogen may be present in exhaust gases and the incompleteness of combustion with air in excess may be caused primarily by the formation of soot from the fuel. In the course of the combustion of liquid or gaseous heavy hydrocarbons, considerable amounts of carbon monoxide and hydrogen may be produced simultaneously with the formation of soot favored by such factors as a local deficiency of oxygen or a sudden cooling of the flame. At ordinary temperatures, however, the velocity of reaction leading to the further combustion of carbon monoxide and hydrogen is much greater than for the solid carbon. Even though the mixture of the fuel with the air of combustion is not always uniform, the gases, carbon monoxide and hydrogen, find the oxygen necessary for their combustion, notwithstanding the small percentage of excess air present. This is because of the turbulence of the burning gases and above all the soot formation itself, which requires a larger percentage of excess air in incomplete combustion. In coal firing, depending on the percentage of the volatile constituents in the coal, soot formation proper is of little importance. In addition to it, however, there is the unconsumed carbon in the ash and the carbon leaving the furnace in the form of fly ash. The presence of carbon monoxide can be of importance as compared with unburned carbon only in the combustion of coke and gases which contain only carbon monoxide and hydrogen as the combustible material. As a rule, it is in just such cases, however, that the combustion is practically complete in the presence of an excess of air. It is only in very small furnaces where the fire-room temperature is comparatively low and where there is a possibility that the gases containing carbon monoxide might suddenly be cooled to the ignition temperature that comparatively large amounts of carbon monoxide may remain unconsumed. In such cases the combustion is usually accelerated by the application of a somewhat greater percentage of excess air, a method which does not help where there is soot formation. The unconsumed carbon remains in the coke ash.

While it has been recognized for a long time that unconsumed carbon causes a loss of heat as a result of incomplete combustion in motors and furnaces, there has been no simple method for its quantitative determination. In the case of Diesel engines the usual method is to determine the intensity of soot formation by directing the exhaust for a given length of time on to a piece of wet paper. Such observations, however, do not permit the absolute measurement of the amount of soot though they may be of value in establishing comparisons. Absolute measurements of unconsumed carbon have been carried out heretofore in isolated instances only in the course of investigations of boiler furnaces, when the amounts of soot, fly ash, and unconsumed carbon have been experimentally determined in the ashes. The determination of the soot in this way naturally must be circumstantial and unreliable, and as a rule determination of unconsumed carbon is omitted on the assumption that the content of carbon monoxide in the exhaust gases as obtained from the Ostwald combustion triangle gives a basis for estimating the extent of soot formation. The author shows that this assumption is incorrect. He plots a combustion triangle of his own and basing his work on the content of carbon dioxide and oxygen in dry exhaust gases as determined by analysis, derives the value of the amount of unconsumed carbon, and hence the loss resulting from incomplete combustion. Incidentally, the percentage of excess air can be determined also from this triangle. The author claims that in the solution of

this problem he uses the exact process first presented in 1927 by Nusselt for the determination of the Ostwald combustion triangle for fuels of uniform chemical composition. He starts from the elementary analysis of a solid and liquid fuel of a general composition, denoting the proportions by weight of the various elements in a kilogram of fuel by c, h, o, n, and s. Then if the mol-volume in any standard state is denoted by Φ the equation for the complete combustion of one kilogram of fuel with the minimum of oxygen may be written as follows:

$$c \text{ kg C} + h \text{ kg H} + s \text{ kg S} + n \text{ kg N} + \Phi\left(\frac{c}{12} + \frac{h}{4} + \frac{s}{32}\right) \text{m}^3\,O_2 = \Phi\left(\frac{c}{12}\,\text{m}^3\,CO_2 + \frac{h}{2}\,\text{m}^3\,H_2O + \frac{s}{32}\,\text{m}^3\,SO_2 + \frac{n}{28}\,\text{m}^3\,N_2\right) \quad [1]$$

If it is assumed that the sulphur dioxide developed in the course of combustion is absorbed by the liquid sealing the analyzing apparatus and if the incomplete combustion is expressed in terms of soot formation, then the analysis of the dry gases of combustion in the case of either complete or incomplete combustion will show only carbon dioxide, oxygen, and nitrogen. It is therefore sufficient to determine by analysis the parts by volume occupied by carbon dioxide and oxygen as the nitrogen content can be determined from the equation

$$CO_2 + O_2 + N_2 = 1 \quad [2]$$

The author proceeds next, upon the assumption that the combustion is complete, to work out the oxygen balance for a cubic meter of dry gases of combustion according to Equation [2], which means that he tries to determine how much oxygen from the air and the fuel itself is used to create the given amount of exhaust gases. The sum of the two must be equal to the quantity of oxygen contained in the products of combustion in one cubic meter of dry exhaust gases plus the oxygen present as free oxygen in the gases of combustion.

The amount of oxygen used in producing the carbon dioxide is equal to the volume of the carbon dioxide itself or to CO_2 in Equation [2]. According to Equation [1], however, the volume of water vapor produced in the process of combustion is in the ratio to the carbon dioxide as $\frac{h/2}{c/12}$. The water vapor formed is, therefore, $H_2O = 6\frac{h}{c}CO_2$ and the oxygen used up in generating it is equal to $3\frac{h}{c}CO_2$. It will be found that to burn the sulphur contained in one cubic meter of gases of combustion, an amount of oxygen is required equal to $\frac{3}{7}\frac{s}{c}CO_2$. The total amount of combined oxygen held in the products of combustion in one cubic meter of dry exhaust gases together with the free oxygen contained in the exhaust gases is equal to

$$\left(1 + 3\frac{h}{c} + \frac{3}{8}\frac{s}{c}\right)CO_2 + O_2 \quad [3]$$

In order to determine the amount of oxygen supplied by the air in the process of combustion as indicated by the content of nitrogen shown by the analysis of the exhaust gases and Equation [2], there must be abstracted from the amount of nitrogen so indicated that part of nitrogen N'_2 which is produced by the dissociation of the fuel.

According to Equation [1]

$$\frac{N'_2}{CO_2} = \frac{n/28}{c/12}$$

or N'_2 is equal to $\frac{3}{7}\frac{n}{c}CO_2$ where CO_2 again corresponds to Equation [2]. The amount of oxygen brought in with the air is therefore

$$\frac{21}{79}(N_2 - N'_2) = \frac{21}{79}\left(N_2 - \frac{3}{7}\frac{n}{c}CO_2\right) \quad [4]$$

The oxygen O_2 produced by the fuel is determined in the same way as the nitrogen. This is done from the ratio $\frac{O'_2}{CO_2} = \frac{o/32}{c/12}$ or $O_2' = \frac{3}{8}\frac{o}{c}CO_2$. From this it would appear that the total amount of oxygen supplied for one cubic meter of dry exhaust gases during the process of combustion is

$$\frac{21}{79}(N_2 - N'_2) + O'_2 = \frac{21}{79}\left(N_2 - \frac{3}{7}\frac{n}{c}CO_2\right) + \frac{3}{8}\frac{o}{c}CO_2 \quad [5]$$

By equating Equation [3] and Equation [5] and eliminating N_2 by means of Equation [2], the following expression is obtained:

$$\left[4.76 + \frac{3}{7}\frac{n}{c} + 3.76\left(3\frac{h}{c} + \frac{3}{8}\frac{s}{c} - \frac{3}{8}\frac{o}{c}\right)\right]CO_2 = 1 - 4.76\,O_2 \quad [6]$$

This equation gives a linear relation between the volume parts of CO and O_2 in the analysis of exhaust gases from Equation [2].

If the values of CO_2 and O_2 are used as rectangular coordinates, Equation [2] gives the hypotenuse of the combustion

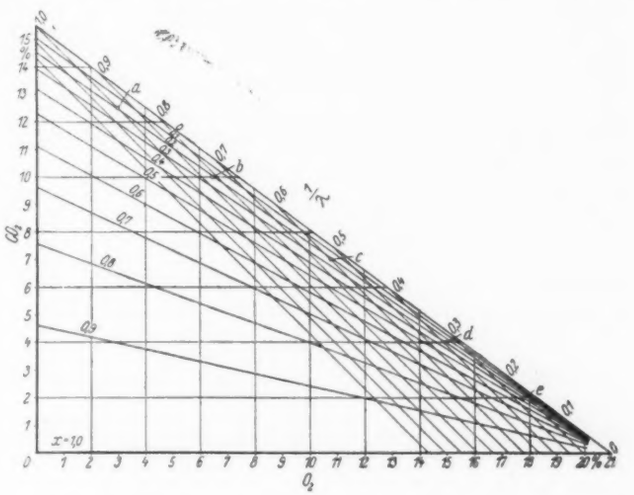


FIG. 1 COMBUSTION TRIANGLE FOR GAS OIL UNDER CONDITIONS OF SOOT FORMATION

triangle, Fig. 1, and no pair of values CO_2 and O_2 obtained by measurement may lie outside of that triangle. For incomplete combustion the analysis of exhaust gases gives a point inside of the triangle.

When one kilogram of fuel is burned, not the entire amount c of the carbon goes with it, but a part x thereof separates out as soot or unburned carbon.

All of the equations given retain their validity for the case of incomplete combustion, providing for c (total carbon consumption) is substituted $(1 - x)c$, or the actual amount of coal consumed. When the substitution is made in Equation [6] the following is obtained:

$$\frac{1}{(1-x)c}\left[4.76\,(1-x)c+\frac{3}{7}n+3.76\left(3h+\frac{3}{8}s-\frac{3}{8}o\right)\right]CO_2=1-4.76\,O_2 \quad \ldots\ldots[7]$$

This equation is generally valid for drawing the combustion triangle under conditions of soot formation. If the part x of the unconsumed carbon remains constant, the connection between CO_2 and O_2 again becomes linear. One may also draw over the triangle a series of straight lines x = constant, all of them going through the point $CO_2 = 0$ and $O_2 = 0.21$. For $x = 0$ the hypotenuse of the triangle or maximum CO_2 content is obtained, and if $x = 1$, then the whole movement is along the O_2 axis. The triangle so constructed makes it possible to read off the values of x and the amount of unconsumed coal determined for one kilogram of fuel by plotting the values of CO_2 and O_2 obtained from an analysis of exhaust gases. With pure carbon having a heating value of 8150 kcal per kg, the loss of heat V due to incomplete combustion is found to be

$$V = 8150\,xc[\text{kcal per kg of fuel}] \quad \ldots\ldots[8]$$

It is impossible to plot straight lines x = constant over the triangle if the fuel consists of pure carbon. For that particular case which appears to be of minor practical importance, however, Equation [7] is no longer valid and the unconsumed carbon cannot be determined from the analysis of exhaust gases.

To calculate the excess of air λ it again becomes necessary to revert to the analysis of dry exhaust gases from Equation [2] and determine the number of kilograms of fuel which produce one cubic meter of such exhaust gases. The amount of fuel so dissociated is found from

$$\frac{12}{\Phi(1-x)c}\,CO_2[\text{kg of fuel per cu m of dry exhaust gases}] \quad \ldots\ldots[9]$$

According to Equation [1] the minimum amount of air necessary to burn a kilogram of fuel is

$$\frac{1}{0.21}\,\Phi\left(\frac{c}{12}+\frac{h}{4}+\frac{s}{32}-\frac{o}{32}\right) \quad \ldots\ldots[9a]$$

and hence, according to Equation [9], the minimum amount of air required to produce one cubic meter of dry exhaust gases is

$$L_{min}=\frac{1}{0.21}\left(\frac{c}{12}+\frac{h}{4}+\frac{c}{32}-\frac{o}{32}\right)\frac{12}{(1-x)c}\,CO_2 \quad \ldots[10]$$

The actual amount of air used per cubic meter of dry exhaust gases, according to Equations [4] and [2], and with due regard to the value of x, is

$$L_{tats}=\frac{1}{0.79}\left(1-CO_2-O_2-\frac{3}{7}\,\frac{n}{(1-x)c}\,CO_2\right) \quad \ldots[11]$$

Equations [10] and [11] finally yield an expression for the coefficient of excess of air

$$\lambda=\frac{L_{tats}}{L_{min}}-\frac{\frac{21}{79}\left(1-CO_2-O_2-\frac{3}{7}\,\frac{n}{(1-x)c}\,CO_2\right)(1-x)}{\left(1+3\,\frac{h}{c}+\frac{3}{8}\,\frac{s}{c}-\frac{3}{8}\,\frac{o}{c}\right)CO_2} \quad \ldots\ldots[12]$$

Here the value of $(1-x)$, as yet unknown, can be eliminated by resorting to Equation [7], which gives the final expression for the coefficient of excess of air

$$\lambda=\frac{1-CO_2-O_2}{1-4.76\,(CO_2-O_2)}\times\frac{\frac{21}{79}\,\frac{3}{7}\,n+3h+\frac{3}{8}\,s-\frac{3}{8}\,o}{c+3h+\frac{3}{8}\,s-\frac{3}{8}\,o}-\frac{\frac{21}{79}\,\frac{3}{7}\,n}{c+3h+\frac{3}{8}\,s-\frac{3}{8}\,o} \quad \ldots\ldots[13]$$

In this equation for λ, in addition to the number of parts by volume of CO_2 and O_2 obtained from analysis of exhaust gases, it is necessary to have only the elementary analysis of the fuel. From this is obtained

$$CO_2=\frac{a-b-\lambda}{a-4.76(b+\lambda)}-O_2 \quad \ldots\ldots[14]$$

where the values of a and b are given by the following equations:

$$a=\frac{\frac{21}{79}\,\frac{3}{7}\,n+3h+\frac{3}{8}\,s-\frac{3}{8}\,o}{c+3h+\frac{3}{8}\,s-\frac{3}{8}\,o} \quad \ldots\ldots[14a]$$

and

$$b=\frac{\frac{21}{79}\,\frac{3}{7}\,n}{c+3h+\frac{3}{8}\,s-\frac{3}{8}\,o} \quad \ldots\ldots[14b]$$

From Equation [14] it is deduced that the lines of constant excess of air are straight lines enclosing with the coordinates CO_2 and O_2 an angle of 45 deg. Their course is therefore considerably flatter than in the Ostwald combustion triangle. Since their points of intersection with the hypotenuse must be the same in both triangles, the new triangle indicates a lower excess of air. In order to plot the straight line $1/\lambda$ = constant, one may start from Equation [14] and calculate only the projections on the two coordinate axes. From Equation [14] it further appears that the projections of the straight line $1/\lambda$ = constant on the hypotenuse when $1/\lambda$ is varied by equal distances from 0 to 1, are not exactly equal, contrary to what has been usually assumed hitherto. If it is assumed that combustion is complete and that the fuel contains no nitrogen, the constants of the elementary analysis of the fuel in Equation [13] may be eliminated by means of Equation [6], which gives

$$\lambda_{\substack{x=0\\n=0}}=\frac{1-CO_2-O_2}{1-CO_2-4.76\,O_2} \quad \ldots\ldots[15]$$

This equation is identical with the conventional formula for complete combustion

$$\lambda_{\substack{x=0\\n=0}}=\frac{N_2}{N_2-\frac{79}{21}\,O_2} \quad \ldots\ldots[15a]$$

This check on the correctness of the calculation shows that the special formula [15], contrary to views repeatedly expressed in engineering literature, holds good even if the fuel contains oxygen. It is only when the fuel contains nitrogen that the

TABLE 1

(Sections of the straight lines x = constant and $1/\lambda$ = constant on the CO_2 and O_2 axes)

x	$O_2 = 0$ CO_2 per cent	$1/\lambda$	$CO_2 = 0$ O_2 per cent
0	15.50	0	21.00
0.2	14.55	0.2	20.00
0.4	13.20	0.4	18.90
0.6	11.13	0.6	17.80
0.8	7.57	0.8	16.67
1.0	0	1.0	15.50

simple formula [15*a*] no longer holds good. The combustion triangle for Diesel oil in Fig. 1 has been plotted by means of Equations [7] and [14] and Table 1. The elementary analysis of the oil is as follows: $c = 0.85$, $h = 1.13$, $o = 0.02$, $n = s = 0$. For purposes of comparison the Ostwald combustion triangle is shown in Fig. 2. The data of exhaust-gas analysis

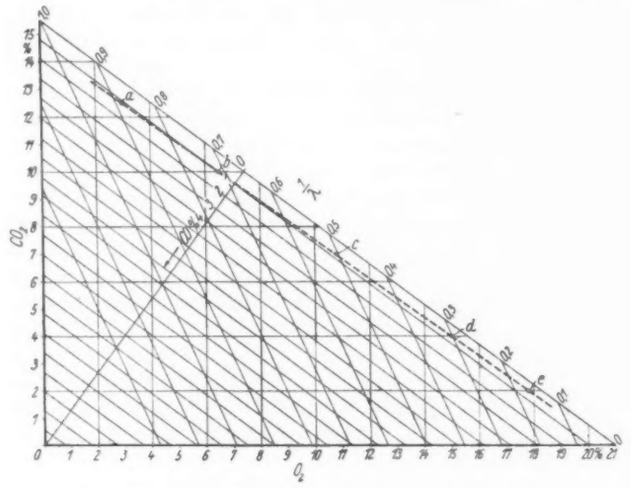


FIG. 2 OSTWALD COMBUSTION TRIANGLE FOR GAS OIL

plotted on the triangle and interconnected by a straight line show a behavior which is usually encountered in investigating the operation of a Diesel engine as a function of its load. Similar values of analysis have been plotted also in the combustion triangle in Fig. 1.

Table 2 gives the data taken from the two triangles but dealing with CO, soot formation, coefficient of excess air, and, above all, the loss through incomplete combustion. In the case of soot formation, the latter has been computed from Equation [8] and for the Ostwald triangle it has been obtained from the well-known equation

$$V_{CO} = 5170\, c\, \frac{CO}{CO_2 + CO} \text{ [kcal per kg of fuel]} \ldots [15b]$$

The new triangle shows the loss to incomplete combustion three times as great as the Ostwald triangle, from which it would appear that the decrease of heat value due to soot formation has been very greatly underestimated heretofore. The losses determined from the two different assumptions are not proportional to each other, as shown by the last column in Table 2. It further appears that, according to both triangles, as the excess of air increases the combustion becomes poorer and the losses due to incomplete combustion greater. In the new triangle this can be seen directly from the position of the individual points, as the straight lines x = constant are also the lines of constant loss of heat value. If the incompleteness of combustion were determined from the formation of CO, there would have been no reason for such an increase and the combustion should have

TABLE 2

(Comparison of fuel analysis in the Ostwald and new combustion triangle)

	Individual values, per cent	Ostwald triangle: CO, per cent	Ostwald triangle: V_{CO}	Ostwald triangle: λ	New triangle: x	New triangle: V	New triangle: λ	$\frac{V}{V_{CO}}$
a	$CO_2 = 12.5$ $O_2 = 3.0$	1.13	403	1.13	0.190	1320	1.00	3.28
b	$CO_2 = 10.0$ $O_2 = 6.5$	0.95	421	1.39	0.210	1460	1.21	3.47
c	$CO_2 = 7.0$ $O_2 = 10.8$	1.75	470	1.98	0.225	1560	1.67	3.32
d	$CO_2 = 4.0$ $O_2 = 15.0$	0.58	624	3.32	0.295	2040	2.62	3.27
e	$CO_2 = 2.0$ $O_2 = 17.8$	1.48	940	6.10	0.410	2840	4.30	3.02

become better with the increase of excess of air. Assuming, however, that soot formation has been the main cause of incomplete combustion, the following explanation may be submitted.

Of each part of the fuel which reaches the engine from the beginning of injection to the time of ignition, a certain amount strikes the comparatively cold walls and is burned there with considerable difficulty and under conditions favoring the formation of soot. The fuel injected after the beginning of ignition, on the other hand, meets with an already organized combustion and therefore probably does not reach the walls at all, with the result that there is only a slight tendency toward formation of soot. Since the total duration of injection even at comparatively small loads on the motor is, as a rule, greater than the duration of the ignition process, the amount of fuel that comes in contact with the walls may be considered in the first approximation as being constant. Because of this, at low loads when the excess of air is greater and the total amount of injected fuel small, the loss through incomplete combustion is relatively greater. The comparison of two triangles shows finally that where soot is formed the coefficient of excess of air λ is smaller than in the Ostwald triangle; the difference is the greater the higher the specific soot formation x. (Abstract of the first part of the article which also contains a combustion triangle for gaseous fuels. Dr. of Engrg. G. Ackermann, of Munich, in *Forschungsheft* 366, supplement to *Forschung auf dem Gebiete des Ingenieurwesens*, vol. 5, issue *B*, May-June, 1934, pp. 1–5, illustrated, *tA*)

Short Abstracts of the Month

APPLIED MECHANICS

Young's Modulus for Steel

THE value of the Young modulus for steel is usually given in books of reference as 29 to 30 multiplied by 10^6 lb per sq in. It is generally recognized that this value is constant within narrow limits for any given steel, whatever the heat treatment applied, provided that the steel is not left in a condition of internal stress. It is also well known that the modulus is approximately constant within somewhat wide limits for ordinary carbon steels of different compositions and for alloy steels of low-alloy content.

However, few highly accurate direct determinations of the Young modulus for steel are available except those made on wires. The present paper gives a record of measurements

carried out on several different types of steel in the form of parts and forgings with the maximum load employed always within the limit of proportionality.

The final results of the tests, carried out in part at the National Physical Laboratory and in part at Woolwich, are given in a table in the original article.

Tests presented in other tables on normalized and annealed specimens and oil-hardened and tempered specimens were carried out at Woolwich only. Table 5 in the original article summarizes all the values to show the effect of the composition on the modulus.

Armco iron and mild steel have a definitely greater modulus of elasticity than medium- and high-carbon steels, but the exact effect on the modulus of increasing carbon content in the latter steels could not be measured directly owing to variations in the manganese content. The results suggest that the Young's modulus of pure iron in the annealed condition would be about 30.2×10^6 lb per sq in., and that, with an increase in the carbon content up to about 0.5 per cent, this value diminishes to approximately 29.7×10^6 lb per sq in., but that in medium- and high-carbon steels the value of the modulus is approximately constant, while additions of manganese tend to raise its value.

In 13-per cent chromium stainless steel, on the other hand, the high-carbon varieties have the greater modulus. The presence of silicon in a carbon steel definitely lowers the value of the modulus, but in 13-per cent chromium stainless steels it appears to have the opposite effect. The presence of nickel in steel causes a reduction in the modulus, while additions of chromium raise its value. Heat-treatment does not appear to affect the modulus, provided that no residual internal stresses are present as a result of the treatment. The modulus was not dependent on the direction of testing (longitudinal or transverse) in heat-treated forgings of good-quality alloy steel, relatively free from non-metallic inclusions. It is considered that the values of Young's modulus recorded in this paper are correct to within $\pm$ 1/4 per cent, and there is no reason to suspect that there would be any important variation in its value for other steels of similar composition. (H. H. Abram, paper before the Annual Meeting of the Iron and Steel Institute, abstracted through *The Iron and Coal Trades Review*, vol. 128, no. 3461, June 29, 1934, pp. 1063–1064, including 5 tables, *eA*)

Cylinder Wear

THIS report was issued by the Research and Standardization Committee of the Institution of Automobile Engineers, of London. An interim report on the same subject was issued in March, 1933, and the present report contains the results of some, though not all, of the experiments carried out since that date. Attention has been devoted to the nature and causes of cylinder wear rather than to possible remedies.

According to the previous report, accelerated wear occurs at low engine temperatures and is attributable to corrosion resulting from the deposition on the cylinder walls of acid-bearing moisture. The reasons for assuming corrosion to be responsible may be recapitulated as follows:

(1) The pitted and discolored appearance of piston rings and cylinder walls after low-temperature operation; (2) the fact that increased wear begins just below the calculated dewpoint; (3) the detection of acids in the water of combustion; (4) the large reduction in wear obtained with hydrogen fuel; and (5) the reduction in wear obtained when using corrosion-resisting materials.

It was pointed out that the acids responsible for corrosion might be any or all of the following:

(*a*) Nitric acid: Oxygen and nitrogen may combine during the explosion to form nitric oxide, further oxidation producing nitrogen peroxide which, in the presence of water, forms nitric acid.

(*b*) Organic acids, such as formic, may be produced as an intermediate product in the combustion of hydrocarbon fuels.

(*c*) Sulphuric acid results from the combustion of sulphur in the presence of water.

(*d*) Carbonic acid results from the solution of CO_2 in water.

It should be noted that, with the exception of organic acids, all the foregoing require the presence of liquid water for their formation and cannot, therefore, be formed above the dewpoint, that is to say, when the cylinder walls are sufficiently warm.

To study the influence, if any, of nitric acid, it was decided to run the engine on an atmosphere free from nitrogen so that the possibility of forming nitric acid was excluded. The mixture of 33 per cent oxygen with 67 per cent carbon dioxide was used. Essentially, it was found that this method of running an engine does not result in the reduction in cylinder wear to be expected if the formation of nitric were the predetermined factor. In fact, in every case a large increase in cylinder and piston-ring wear was recorded.

Figures in the original article indicate that this method of operation has introduced a corrosion-accelerating factor which has completely swamped any possible reduction due to the elimination of nitric acid. This factor was probably the presence of large quantities of CO_2. This led to tests in which hydrogen was used as a fuel so that the products of combustion, although containing large quantities of water, were completely free from CO_2. It was found that the addition of CO_2 increased the rate of wear but was not responsible for the entire wear obtained with gasoline. The attempt to determine the effect of increase of solubility of CO_2 with pressure as a factor in cylinder-wall corrosion had to be abandoned.

The sulphuric-acid or sulphur content in high-grade gasolines was found not to have any important influence on cylinder wear at low operating temperatures. Sulphur content of 0.1 or higher was found, however, to have a marked effect in accelerating cylinder wear.

The effect of organic acids, such as formic and acetic, showed the necessity for rapid warming up when alcohol blends are used. On the other hand, it would appear that organic acids do not cause any corrosion at high cylinder temperatures.

Referring to Fig. 9 in the original article (reproduced from previous report), it will be noted that at normal operating temperatures cylinder wear is largely independent of oil consumption, so that it would be anticipated that the small amount of lubricant which can be introduced in the form of an upper-cylinder lubricant could hardly have much effect in reducing wear. This was confirmed by tests carried out on an engine operated under rather severe conditions, the lubrication from the crankcase being restricted in order that any possible improvement due to an upper-cylinder lubricant might be made more apparent.

It would appear to indicate that the field for upper-cylinder lubrication, if any, is in relation to starting from cold, particularly if arrangements can be made to add temporarily a high percentage of oil to the intake, provided this can be done without interfering with carburetion or ignition. In this way, the lubricant is only consumed when it is most likely to be effective.

Several series of stopping and starting tests were carried out. The results are given in the original in the form of curves. (Institution of Automobile Engineers, Confidential Report,

no. 7500 *B*, class 42, 251, C. G. Williams, Research Manager, issued Mar. 24, 1934, 21 mimeographed pp., 14 figs., *e*)

Thermoelasticity—Fatigue and Corrosion Cracks

THE exhibit by Professor Coker at the Conversazione of the Institution of Civil Engineers on June 13, 1934, dealt with the application of the principle of thermoelasticity. Professor Coker in association with Prof. A. V. Hill has developed a means of deducing the local stress in a loaded body from observations of the temperature change occurring at selected points in the body when the load is applied. The method is applicable to actual bodies or structures and may be applied to bodies, the nature of which or the nature of the load applied to which is such that the determination of the stress existing in them is difficult or impossible by any ordinary means.

Among other things Professor Coker exhibited the use of the method of thermoelasticity to determine the stress existing in a hemispherical dome loaded with a concentrated force at its summit.

Prof. Frederic Bacon exhibited some new photographic studies of cracking and fracture caused by fatigue and corrosion. A year ago (*The Engineer*, June 23, 1933) Professor Bacon demonstrated the technique which he had evolved for studying the manner in which specimens subjected to a fatigue test fail by the development of creeping cracks. In a fatigue test, as ordinarily conducted, the battering of the crack faces together during the last few cycles before fracture occurs destroys much of the evidence which might be used to deduce the manner in which the crack originates and spreads. Professor Bacon's method of investigation consists of employing a very sensitive trip gear, which stops the operation of the testing machine before final failure of the specimen and the accompanying battering action begins. The cracked, but as yet unbroken, specimen is then fractured under a tensile load, with the result that the undamaged crack faces are revealed for study. As explained and illustrated a year ago, it is found in the case of a typical specimen that the crack starts as a small semi-circle and develops along a front of a gradually increasing elliptical form, ultimately becoming a straight line coincident with a diameter of the specimen. This diameter, according to a theory of failure by creeping cracks developed by Professor Bacon, should be tilted back at an angle of 15 deg relative to the diameter normal to the radius on which the initial semi-circular crack begins. The whole theory has been very completely verified by laboratory and service failures under fatigue.

Figs. 3 and 4 in the original article illustrate Professor Bacon's "heat tinting" method of measuring the speed at which fatigue cracks develop radially. Fig. 3 represents a specimen of low-carbon, 5 per cent nickel steel, tested under stress limits of ±20 tons per sq in. After 30,000 cycles the machine was stopped and a Bunsen flame placed beneath the middle of the specimen, which was then slowly turned by hand to secure uniform heating. When the surface of the specimen had reached a blue heat, the flame was withdrawn and the specimen was allowed to cool. When it was cold the machine was restarted and the test continued for a further 5500 cycles. The lighter ring outside the core indicates the amount by which the crack penetrated during the resumed test, the outer ring showing the penetration up to the instant at which the test was interrupted for the heat-tinting treatment. The specimen shown in Fig. 4 of the original article was of 0.34 per cent carbon steel. The heat-tinted section shows the penetration of the crack after 60,100 cycles, and the inner light area the penetration after an additional 1200 cycles. (*The Engineer*, vol. 157, no. 4093, June 22, 1934, pp. 634–636, illustrated, *d*)

ENGINEERING MATERIALS

Two-Ply Stainless-Clad Steel Pipe

EIGHTEEN hundred feet of pipe have been fabricated by arc-welding from two-ply stainless-clad steel. The pipe is 2 ft to 5 ft in diameter, 1/4 in. thick, and will carry compressed air from rotary turbo blowers to aeration tanks at the Milwaukee sewage-disposal plant on Jones's Island. It is said that this is the first time that stainless-clad steel has been used for this type of work. Most of the sections of the pipe are 54 ft long. These are made up of nine plates 1/4 in. thick. Each single plate is formed and placed in a special welding clamp for making the longitudinal seam which is a plain butt weld made with 18-8 stainless-steel electrodes on the inside and with heavily coated mild-steel electrodes on the outside. The welding speed is said to be about 50 ft per hr. (From a release by A. F. Davis, Vice-President, The Lincoln Electric Co., Aug. 10, 1934, *d*)

White Bearing Metals for Severe Service

RECENT development, in the internal-combustion engine in particular, has produced a combination of three difficult conditions: High bearing pressures, high temperature, and rapid change of loading. The connecting-rod and main-crankshaft bearings in such engines have to face conditions more severe than in any other important class of engine or machine. In view of their superior merits, particularly at elevated temperature, tin-base alloys have been used in preference to lead-base alloys, and have undoubtedly given excellent service under severe conditions. The conditions of service, however, are increasingly advancing to a stage that calls for further improvement in tin-base alloys, or alternatively, for the substitution of some other type of alloy.

Consideration is given to the theoretical functions of an ideal white metal, and the manner in which the stresses produced in service tend to cause failure by cracking. Since the normal action of the stresses are compressive, special attention is given to the tension stresses which are shown to lower the fatigue range of the metal and to open up incipient cracks. Based on this analysis the mechanism of crack formation is discussed.

The following directions in which improvement in service behavior may be secured are considered: (1) Diminishing the intensity of the stresses in the metal by modifications in (*a*) certain features of design and (*b*) the material used for the liner; (2) increasing the fatigue-resisting properties of the white bearing metal in respect to which results obtained in preliminary investigations of the fatigue properties of high-tin-antimony-copper alloys with and without addition of a further element are given.

Although failure by pounding is occasionally important, the outstanding difficulty experienced in current severe conditions, particularly in internal-combustion engines, is a peculiar form of fatigue-cracking. After a period of service under pulsating stress and high temperature, numbers of fine cracks appear on the surface of the bearing and spread in all directions to form a network similar in appearance to a tessellated pavement.

For some considerable time the bearing continues to run in this condition without overheating or other difficulty, but eventually the cracks spread laterally below the surface of the metal, and when one or more pieces become detached the bearing fails owing to increase of friction and overheating produced as a consequence of the destruction of the surface and faulty flow of oil. The bearing melts out. To cope with this trouble, it is

important to ascertain the cause of the initial cracking and the reason why the cracks spread laterally in such a manner that pieces become detached.

As the action of tension seems necessary before cracks can open or even before fatigue can be caused by variations of pressure of reasonable magnitude, the author considers different causes which, in different cases, may tend to produce tension in the white metal. Making certain assumptions he gives a formula for the strain that has to be produced by tension after cooling to a certain temperature to neutralize the contraction due to cooling. From the equation which he gives it would appear that a difference in temperature of 100 C would produce approximately 6.8 tons per sq in. in the white metal in circumferential and longitudinal tension had the metal remained static. In reality, however, a range of temperature only a little greater than 50 C produces tensile stresses reaching the yield point of any ordinary white metal.

The author considers several ways of obtaining improved service from white metals. Among others, reduction in the intensity of the forces on the white metal, the most promising metallurgical contribution appearing to be in the direction of reducing the tensile forces that lower the fatigue range of the metal and the use of white metals of superior fatigue-resisting properties. The chief governing factor appears to be the amount of antimony in solid solution. From other investigations additions of antimony appear to be beneficial. (D. J. Macnaughtan, paper no. 673 before the *Institute of Metals*, September, 1934, Manchester, England, pp. 285–299, illustrated, *e*.)

This paper is followed by papers nos. 674, 675, and 676 dealing, respectively, with the behavior of white bearing metals when subjected to indentation tests, tensile tests, and pounding tests. A modified form of the Stanton impact tester suitable for the testing of white metals by pounding at different temperatures is described. Results on cylindrical specimens are given, and the unsuitability of this type of test piece is shown. The use of bearing-shaped specimens with a cylindrical indenter is described. Results are recorded for eight different white-metal bearing alloys and a lead-alkali alloy, cast under various conditions, and tested at 18, 100, and 150 C. A babbitt metal with an addition of cadmium gave the greatest resistance to pounding.

Steel Forgings

GOOD forging ingots are invariably cast in metal molds. The most desirable type is of round design with the proper number of heavy longitudinal corrugations and increasing in cross-section from the bottom to the top. Sizes of forging ingots vary from about 16 in. to 108 in., nominal diameter, and in weight from about 4000 to 450,000 lb. The design of ingot molds, involving the relation of the various dimensions, shape of corrugations, etc., is a very important feature. For each size and type of ingot a bogey limit for pouring conditions is established, largely based on experience for both carbon and alloy steel.

Specifications frequently attempt to cover in detail required methods of forging, supplemented by definite physical requirements for test bars taken from different planes as related to the major axis of the piece. Unless such specifications cover a single type of forging, such, for instance, as the present Navy requirements for boiler drums, they are bound to fall short of their objective and will often result in the furnishing of far less satisfactory product than is the case when forging work can be planned, based on a knowledge of the service requirements.

The author discusses the case of hollow cylindrical forgings. In forgings intended for rotating members operating at very high speeds, forging operations based only on elongation from the original ingot may be less satisfactory than a combination of operations. Because of this, forging operations in a piece of this character involve upsetting of the body so as to favor radial stresses and in many cases partial punching and hollow forging of the body. In the production of cylindrical forgings intended to resist internal pressure, such as boiler drums and oil-refinery vessels, where the metal in the wall is subjected to an appreciable stress, the boring of a solid forging cannot be classed as an entirely safe procedure. In the production of such forgings the original ingot is first forged by rounding, and after the removal of the discard metal is upset to a sufficient degree to work thoroughly the whole mass in a direction at right angles to the axes. The center of the block is then removed by punching or hot trepanning.

A very interesting and efficient method for producing hollow, forged cylinders, which is applicable when several cylinders of one size are required, is by upsetting, punching, and drawing. In this process the hot ingot, after rounding up and removal of discard, is upset, then placed in a large container, and a further upset is followed by punching to form a heavy-walled cup-shaped blank. This cup-shaped blank is then drawn into a cylinder by passing through a succession of dies in a heavy draw bench which reduces the wall by successive steps. This process, due to the favorable distribution of forging work in every direction, produces remarkable uniformity of properties throughout the forging.

Forging operations involving longitudinal forging under flat or "V" dies, upsetting, punching, hollow forging over mandrels, either for enlargement or elongation of the forging, are resorted to with due consideration of the purposes for which the forging is to be used and the customer's requirements for physical characteristics. Since the prime object is to work the metal in the direction that will increase its resistance to the maximum service stresses, it is important before planning a forging operation on a given piece to have a rather thorough knowledge of the character of service contemplated and an approximation of the magnitude and direction of the service stresses which will be imposed.

The matter of heat treatment is discussed next. A serious fault in many standard specifications is inclusion of tables of physical properties which are based on average values obtainable, but which are specified as minimum requirements and used as a basis for acceptance or rejection. In the case of large forgings this presents serious difficulties through necessity of retreating product which is equal in physical properties to some of the forgings used as a basis for formulating the specifications.

With such a situation there is a strong temptation for the manufacturer to alter heat treatment to meet the requirements of the specification with a safe margin, possibly resulting in less desirable treatment than was given the material on which the specification was based.

As a general practise, actual physical properties of forgings will be kept from 10 to 20 per cent in excess of the rejection limits specified as a manufacturing safety factor so as to prevent the necessity for frequent re-treatments. If minimum values rather than averages for the class of material desired were used as a basis for establishing rejection limits, the original intent of the specification would be realized and in many cases considerable money would be saved to the consumer. (P. E. McKinney, Metallurgical Engr., Bethlehem Steel Co. in *Journal of the American Society of Naval Engineers*, vol. 46, no. 3, August, 1934, pp. 357–368, illustrated, *d*)

FUELS AND FIRING

Briqueting Coal Without a Binder

THIS process presents no difficulty experimentally with a small amount of coal but is difficult to operate with large amounts. This is due basically to the fact that the difference between the softening and the volatilizing temperatures is very small. Because of the poor heat conductivity of coal, it is very difficult to obtain the uniform and closely controlled heating of it which is needed to permit production throughout the coal charge of the desired plasticity for briqueting by pressure alone. It is said that this problem, however, has been apparently solved by the Coppee Company of Brussels. To be used in this process the coal must contain enough bitumen so that a portion can be volatilized to produce gas and tar without destroying the plasticity of the coal required in the compressing stage. Some of the details of the process are described in the original article and it is stated that a unit is being built in Belgium. It is not yet known whether this process will permit the briqueting of lean coals without binding material.

The Apfelbeck process claims to be able to briquet fine coal without a binding medium. A plant using this process is in operation at the Rtanj coal mine in Jugoslavia. In this mine the proportion of fine coal is high and the coal has from 30 to 40 per cent or more ash.

The fine coal from the washing plant, after draining, still contains about 28 per cent water; this is reduced to 0.5 to 1.5 per cent in rotary drums in which direct heat is supplied by hot gases passing through the drum in counter-current to the travel of the coal. Although the velocity of the gas stream is low, a certain amount of dust is carried in the gas and is separated in a cyclone dust separator. This dust is either added to the dried coal or used to heat the drums. The direct heating of the coal causes the output of the drying drums to be high. The press handles coal up to 3 mm in diameter; the maximum pressures used amount to 1500 to 1600 atm, and the coal is compressed at a temperature of 80 to 100 C. There is no increase of temperature due to friction or compression in the press, because the heat carried away by radiation from the press-ring prevents this.

Some data as to the plant and the press used are given in the original article. It was feared at first that the high compression used in the press would produce briquets of such density as to affect adversely the combustion, but the contrary has proved to be the fact. The briquets behave in the fire like the same coal in lump form; they do not break down into particles of the original sizes of the coal particles, but more or less retain their form until nothing but ash remains. (*The Fuel Economist*, vol. 9, no. 105, June, 1934, pp. 359–361, 2 figs., *d*)

INTERNAL-COMBUSTION ENGINEERING

Evaporative Cooling in Aircraft Engines

THIS method of cooling is said to have made great progress in England in the past five years and a practical method has been developed for increasing the capacity of a cooling fluid for heat dissipation by using the latent heat of vaporization. The evaporative cooling system used in England is vented to the atmosphere which differs from the American practise. Fig. 3 shows diagrammatically the system used in England. The steam from the cylinder jacket passes into a "header tank," wherein the moisture from the steam is separated and added to the water already in the tank. The dry steam then passes up to the wing condensers, the condensate being returned to the cylinder jacket via the circulating pump. Owing to the fact that the condensers could not cope with the changing rise and fall of temperature under varying conditions of flight, it was found necessary to have some means of controlling the amount of cooling within reasonable limits. To do this a honeycomb radiator was mounted under the fuselage and a mechanical means of raising and lowering it by the pilot was installed. This system is used in the Hawker "Hart." The condensate and uncondensed steam is taken from the wing condensers and passes through the bottom radiator, where it is finally condensed and cooled before returning to the cylinder water jacket.

Experiments were carried out at the Royal Aircraft Laboratories in 1927 on a Bristol Fighter to ascertain the advantages of evaporative cooling. The results were promising and showed the necessity for further development. The author discusses next the matter of capacity to dissipate heat from the system and points out that the amount of cooling surface required is

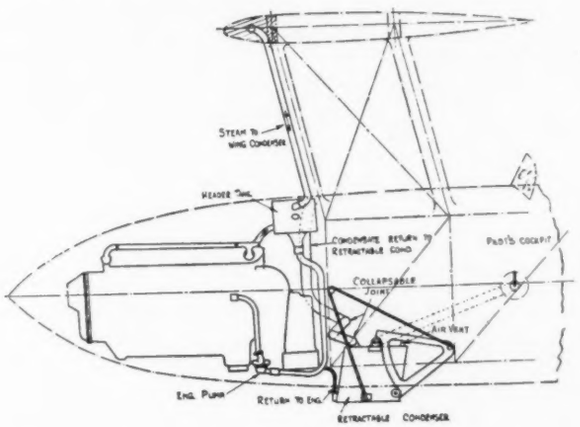


FIG. 3 DIAGRAMMATIC REPRESENTATION OF THE PRESENT BRITISH SYSTEM OF EVAPORATIVE COOLING IN AIRCRAFT ENGINES

not constant for any particular engine, but varies with the atmospheric conditions and the climb characteristics of the aircraft. The factors necessary in estimating the surface required are discussed in the original article. The condensers have to get rid of the latent heat of the steam and the quantity of steam generated is a big factor in the design. As the heat transferred from the surface of the wing condensers to the atmosphere must pass through the boundary layer, the latter's condition becomes of great importance and at some point the laminar layer becomes turbulent. It is, therefore, important to keep the surface of the wing condensers as clean as possible. The rest of the article deals with details of the condensers.

The subject of retractable condensers comes next, followed by a discussion of the header tanks.

To enable the pilot to know when the radiator is too far within the fairing, i.e., when the radiator is not condensing all the steam received from the wing condensers, a warning device is fitted to the bottom of the air vent, which, when steam passes to atmosphere, makes electrical contact with a small lamp fitted on the instrument board, giving the pilot warning that steam is being lost. The author can foresee the day when some electrical device will operate the radiator in and out, functioning by the emission of steam through the air vent. This air vent must protrude clear of the fairing when the radiator is in the full-up position. In this position also, the sump must be in the slipstream. (*The Aircraft Engineer*, supplement to *Flight*, vol. 26, nos. 1318–13 and 1322, Mar. 29 and Apr. 26, 1934, pp. 23–24 and 25–28, 5 figs., *d*)

MACHINE PARTS

Intermittent-Motion Mechanism

A SIMPLE but effective mechanism giving an intermittent movement to a driven shaft from a continuously revolving shaft is illustrated in Fig. 4.

Gearwheel *C* is specially shaped and is the driving member. It is recessed out at one end to receive the other parts of the mechanism, and is a free-running fit upon the stationary shaft *A*.

Attached to the front face of the shoulder on shaft *A* is a small crankpin *F* with which engages a connecting arm *E*. The other end of this is linked up to the working end of a small pawl *G*, which is, in its turn, fulcrumed to the face of the rotating gear *C*.

The fitting of this pawl *G* with lever *E* is shown in the sketch

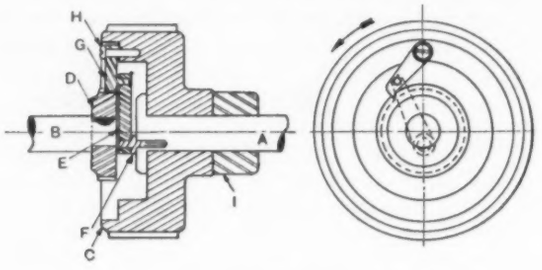


FIG. 4 INTERMITTENT-MOTION MECHANISM

simply by means of hole-and-pin engagement. This is quite suitable for high rotational speeds and very light loads, but for heavier loads the pawl should be in deeper engagement with the ratchet-wheel teeth, and for greater periods of each rotation.

The connecting lever *E* then has an elongated slot in which slides freely a small die or block, this swiveling upon a pin attached to the pawl *G*. The length of this slot determines to some extent the ratio of engagement time of pawl per revolution of driving member. (Letter signed W. H. in *Mechanical World*, vol. 96, no. 2485, Aug. 17, 1934, p. 152, 1 fig., *d*)

Ford Cast Crankshafts

THE majority of these crankshafts have been in constant service for at least two years while some have been in use for varying periods up to five years. Up to the present none has failed in service, shown distortion, appreciable wear, or improper crystallization. Crankshafts are apparently immune within practical operating limits to the fatigue factor. The metal in the cast crankshaft partakes somewhat of the characteristics of steel, of gray iron, and of malleable iron, and therefore cannot be classified under any of these headings. It is mentioned in this connection that the use of alloys in ferrous-foundry practise has increased so rapidly in recent years that nomenclature has lagged behind, and the American Foundrymen's Association has at present a committee working on nomenclature for the wide variety of steel castings, and a committee for a similar purpose in the malleable field is in the process of formation.

Metal charge for the cast crankshaft is made up of approximately 50 per cent steel scrap and 50 per cent return crankshaft scrap, that is, metal from the gates and risers. Suitable amounts of various alloys are added to produce a metal of the following analysis: Carbon 1.25–1.40 per cent; manganese 0.50–0.60 per cent; silicon 1.90–2.10 per cent; chromium 0.35–0.40 per cent; copper 2.50–2.75 per cent; phosphorus 0.10 per cent maximum; sulphur 0.06 per cent maximum. Patents have been applied for covering the mixture and the method of molding.

A duplexing process has recently been developed in which the metal is melted in a cupola, tapped into an air furnace with a holding capacity of 30 tons, and drawn off as required. Two cupolas each with a melting capacity of 14 tons per hr, are capable of supplying metal for an anticipated production of 4800 crankshafts per day.

Information as to the method of handling the metal, molding, and cores is given in the original article.

Manifestly, the greatest accuracy must be maintained in the thickness of the cores so that the entire stack will produce castings held to extremely narrow tolerances. The extent to which this accuracy is maintained is reflected in a report for 1912 castings which showed a loss of only seven from the following causes: Shifted core, two; slag, one; broken cores, two; poured short, one; shrink, one. Thus in the total loss from all causes only five were attributable to the cores, a practically negligible loss of two-tenths of one per cent.

Brinell hardness of the castings varies from 269 to 302, as compared with 200 for forged shafts before and 444 after machining and hardening. However, the hardness of the cast shaft is uniform throughout, while the forged shaft presents varying degrees of hardness from the outside to the center. It is claimed that this factor is responsible for the marked superiority of the cast shaft over the forged shaft in resistance to torsional stress and evidence of fatigue.

A machine was designed to measure fatigue in crankshafts and used during the development period. This test is now applied only occasionally. On the other hand, a torsion-resistance test forms part of the regular routine in the finishing shop. Every shaft on the way to the assembly line is placed in a fixture where a twisting strain of 40,000 lb is applied. It is claimed that this is approximately ten times the stress to which the shaft will be subjected at any time in service. In this test a flange is attached by four bolts to the driving end of the shaft. This flange in turn engages one end of a short horizontal member in which the vertical pressure of a hydraulic plunger at the other end is translated into a revolving movement at the flange end. (Pat Dwyer, *The Foundry*, vol. 62, no. 4, April, 1934, pp. 14–17 and 47, 8 figs., *d*)

MARINE ENGINEERING

Scimitar and Unislip Propellers

THE Scimitar propeller has recently been patented by the Manganese Bronze & Brass Co., London, England. It is claimed that each section of the propeller is shaped to develop the maximum efficiency in the conditions of flow applicable to that particular radius. The present article does not describe the design of the propeller, which is to appear in a subsequent article, but gives data of tank-experiment trials conducted at the National Physical Laboratory in Teddington.

Recently the Unislip Propeller Co., Ltd., of Newcastle-on-Tyne, England, introduced a new design of propeller which has already been applied to a number of vessels of various sizes. In this propeller virtually double blades are employed. Each of the blades comprises a "primary" and a "reaction" blade which differ not only in relative size and shape but also, and to a very large extent, in pitch distribution and the nature of the streamlining of the blade cross-sections which are of airfoil form.

It is said that the action of an ordinary screw-propeller blade is accompanied by the formation of a vortex created by the flow of water past the back of the blade. It is now claimed that in the new Unislip screw the reaction blade is interposed in the region of the vortex formation which causes the flow past the

back of the primary blade to be deflected into the channel formed between the back of the primary blade and the driving face of the reaction blade. The cross current thus formed prevents the formation of the main vortex, and by this means the large amount of energy which is normally wasted in setting a mass of water in rotation is utilized for increasing the fore-and-aft thrust. This principle of operation is associated with a complex pitch variation on both the primary and the reaction blades, the purpose being to operate each element of the blade surface, whether situated on the primary or reaction blade, at optimum efficiency. (*The Marine Engineer*, vol. 57, no. 677, February, 1934, pp. 46–47, for account of the Scimitar, and p. 60 for the Unislip propeller, the latter with 3 figs., *d*)

POWER-PLANT ENGINEERING

The Rotary Economizer

FIG. 5 shows this economizer in section (Simmons patent). This was erected on the site previously occupied by a smooth-pipe economizer which was replaced in order to increase the steam output. Feedwater at boiler pressure from the feed pumps enters the hollow shaft equipped with glands illustrated in detail in the original article. It passes up the shaft and is distributed to the copper pipes of the rotor by means of six connecting pipes. The stream of water moves from the outside to the inside while the smoke and gases move in the opposite direction. The heated water then passes to the hollow part of the shaft at the other end and on to the boiler. The smoke and gases come from the boiler under the economizer through a short suction chamber and, on account of the strong centrifugal action, are forced between the tubes and plates to the outside casing, ultimately passing through the main flue to the chimney. One such economizer was installed in May, 1932, and has operated for 7860 working hours without outage.

Beginning first of all at the water inlet, there is shown in Fig. 6 the type of gland which is used for both the water inlet and outlet. The possibility of adjusting the gland housing in both the horizontal and vertical directions by means of the bolts and wedges *C*, and thereby maintaining the concentricity of the gland pipe *D*, is especially to be observed. As the whole of the gland body *A* can be drawn away after loosening the bolts, it follows that the repacking of the gland is a relatively simple matter. With an inlet-water temperature of 50 to 60 C the packing on the inlet side has stood up for 5500 working hours, and on the outlet side with a temperature of 140 to 190 C for 2800 working hours. It is found with this design that both glands need to be only lightly tightened, so that the friction loss is relatively low. The stop bush is also fitted with forced lubrication, and it is interesting to report that in the boilers which have worked for 5500 hours without cleaning, not the slightest trace of oil was found. The gland pipe, which is coupled to the main shaft by means of a flange, does not show the slightest sign of wear.

The most important part of the economizer has to do with the pipe system and the circulation of water therein. Fig. 7

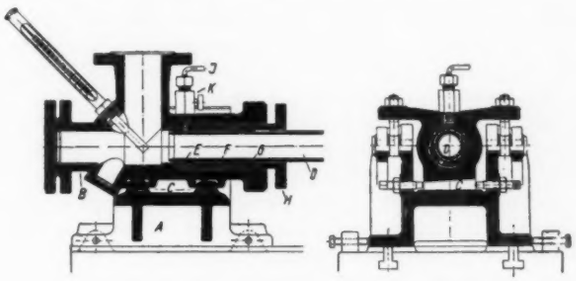


FIG. 6 GLANDS IN ROTARY ECONOMIZER

shows a section through the machine which indicates the formation of the single pipes into groups, and at the same time shows the water distribution in the rotor.

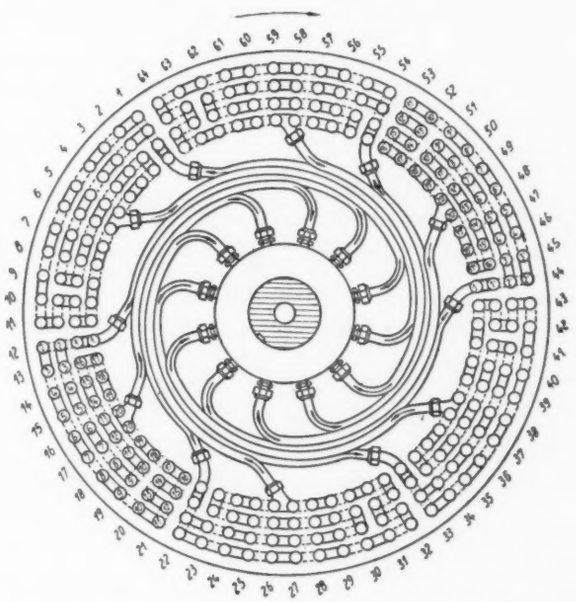


FIG. 7 ARRANGEMENT OF THE PIPE SYSTEM IN THE ROTARY ECONOMIZER

It will be seen that the water entering the hollow shaft is divided into six separate streams which leave the shaft symmetrically. If we follow two of the pipe groups which lie at approximately opposite sides of the diameter, it will be seen that the individual pipes in the row through which the water streams are indicated with the numbers 1, 2, 3, ... 20, and the pipe groups lying at the opposite end of the diameter with numbers 1′, 2′, 3′, ... 20′. Further, we notice that the pipes which have the same base number are at the same distance from the rotating axis. As the rotor has a speed of 265 to 300 rpm it follows that the pipes which have the same base number are practically in the same temperature zone of the smoke and gases, and this leads to the further result that the temperature of the water pass-

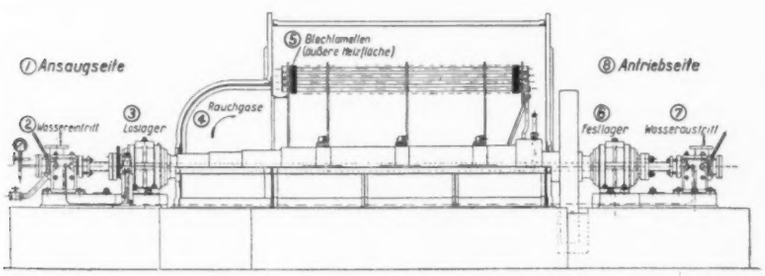


FIG. 5 SECTION THROUGH ROTARY ECONOMIZER

(1 = Suction side; 2 = water inlet; 3 = loose bearing; 4 = smoke and gases; 5 = ring plate (external heating surface); 6 = fixed bearing; 7 = water outlet; 8 = driving side.)

ing through these particular pipes is practically the same. This arrangement of the pipes, therefore, is of especial importance when the feedwater is hard or contains foreign matter. With the heating of water which is not completely softened from 60 to 100 C, there will be a separation of part of the salts in the rotating economizer, and as there is in the whole system a centrifugal action, these salts will be thrown on the outer half-circle of the pipes. As the amount which is thrown out will be proportional to the water temperature, it follows that the solid formations in the pipes at opposite ends of the diameter will be the same. The weight increase of the rotor due to this deposition will be symmetrical and therefore can in no way influence the quiet and steady running of the rotor. The author's practical experience with the plant has confirmed the truth of this view. (First instalment in *The Steam Engineer*, vol. 3, no. 10, July, 1934, pp. 429–431, 7 figs., *d*, of an article by Rolf Schruf, of Dusseldorf, being a translation of an article published in *Mitteilungen aus den Forschungsanstalten*, Gutehoffnungshütte Konzerns, vol. 11, no. 10, 1934.)

Submerged Combustion

THE author refers particularly to machinery developed by Brunler (MECHANICAL ENGINEERING, Vol. 47, No. 5, May, 1925, p. 358), C. F. Hammond (*Ibid.*, Vol. 51, No. 9, Sept., 1929, p. 695), and Kemp. The higher cost of fuel used in submerged combustion is offset by the extremely high efficiencies obtained. The Hammond heating system reports an efficiency of 94.6 per cent of the gross heating value, or 105.8 per cent of the net heating value of the fuel.

In connection with the matter of evaporation the following is stated: The condensation of part of the water formed in combustion allows this latent heat to be used, thus the net heating value of the fuel is exceeded when the burner is used to heat a liquid.

The products of combustion leave the solution saturated with water vapor, thus the vapor pressure of the solution controls the quantity of water vapor carried away. As the vapor pressure of the solution never equals the total pressure because of the gases, the evaporation of liquid will take place at a pressure less than the total pressure. Thus submerged-combustion evaporation is the equivalent of evaporation under reduced pressure, just as in the case of a steam distillation. Under atmospheric pressure water is evaporated by submerged combustion at a temperature of about 90 C.

The corrosion in submerged-combustion apparatus can be controlled more easily than in other types of heat-transfer equipment. In the usual type there is a large metal surface through which heat must be transferred. As this is at a temperature above that of the body of the corrosive liquid, the corrosion will be relatively severe. In submerged combustion the heat transfer is from gas to liquid. The containing vessel does not transfer heat so it is at the same temperature as the liquid. It is subjected to little thermal stress so it may be constructed of stoneware, or if of metal, its life is much longer than if it were a heat-transfer medium. The burner is the only part of the submerged-combustion apparatus which is at a temperature above that of the solution. The burner being relatively small, it may be constructed of the most resistant materials at a comparatively low cost.

Some of the advantages of the employment of submerged combustion for heating and evaporation of salt solutions, in particular concentration of phosphoric acid, are mentioned.

The University of Washington undertook experiments on some of the problems of interest to local industry where submerged combustion seems to be applicable. (Kenneth A. Kobe, Dept. of Chemical Engineering, University of Washington, Seattle, Wash., in *Chemical and Metallurgical Engineering*, vol. 41, no. 6, June, 1934, pp. 300–302, *d*)

SPECIAL MACHINERY

Sectional Drive for a Cardboard-Making Machine

A SECTIONAL drive for a cardboard-making machine was delivered by Brown Boveri to a paper mill in Denmark. The cardboard-making machine itself has a wire width of 3325 mm and is equipped with two wire parts for making either ordinary paper or stronger packing paper, as well as ordinary and duplex cardboard up to 800 g per sq m. The cardboard from the cylindrical wire, which chiefly serves as a filling mass to attain the desired thickness, can be composed of cheap fibrous material, while the covering coming from the plan wire must be made of higher grade material to provide the necessary resistance to external stressing.

Each driving set is composed of a spray-waterproof direct-current motor and a completely enclosed reduction gear with the gear wheels running in oil. The motor and reduction gear are connected by a flexible coupling in the form of a conical pulley. The sectional frequency generator, also completely enclosed, is driven from the conical pulley and generates a three-phase voltage of variable frequency proportional to the speed of the sectional motor. This frequency is compared in the draw regulator to the master frequency, common to all the sets, through the agency of an electrical differential, and the speed of the sectional motor is immediately corrected if there is any deviation from the value set. The setting of the paper draw between the different sections of the machine is carried out by displacing the driving belt on the conical pulley of the sectional frequency generator. This displacement is made with the aid of a special adjusting device on the generator, which carries a millimetric scale and allows of a very close adjustment.

The drive of the store cylinder is mounted on a pedestal which is considered to be the most convenient layout for driving the shaft of this big cylinder, the axis of which is at a considerable height. Only cables of small diameter are required on this installation. The original article describes the cooling of air for the motors, the control set, and the switchboard. (E. Oschwald, *The Brown-Boveri Review*, vol. 21, no. 8, August, 1934, pp. 152–153, 2 figs., *d*)

SPECIAL PROCESSES

Production of Collapsible Tubes

THE process here described is employed at the United States plant of the Globe Collapsible Tube Corporation. The pigs of refined tin, 99.8 per cent pure, are melted in gas furnaces at a temperature ranging from 480 to 500 F. Copper to the extent of 0.5 per cent is added to the molten tin to increase slightly the hardness. The tin is poured into cast-iron molds and the ingot subsequently reduced in thickness and lengthened by passing between the rolls. The practise is to run the ingots through in lots of 100. After one pass of all pieces, the rolls are adjusted closer together and the entire lot is run through again, this being repeated three or four times. In this rolling process the increase in width which is originally 4 in. is negligible, but the length grows from the original 16 in. to 5 or 6 ft.

The next operation consists of punching the slugs from the metal strips. The slugs are next tumbled for a minute or so in a barrel to coat them with a very thin film of oil. Each slug gets only a trace of oil but it is upon this trace of oil that suc-

cessful extrusion to a large measure depends. If the slugs are fed to the extruding die without having first being given a slight oil film, the tubes crumble and tear while they are being formed. The oil provides sufficient lubricant to make the tin slide over the punch edge with minimum friction. From 50 to 100 tons pressure is employed in the extruding operation. The extruding process cannot be described here because of lack of space. Tubes are extruded at a rate of 44 per min. (*Machinery* (London), vol. 44, no. 1140, August 16, 1934, pp. 573–576, 4 figs., *d*)

WELDING

Seam Welding Controlled by Electronic Discharge

IT HAS been found before that there is more advantage in working in seam welding with intermittent or modulated power than with a steadily flowing current, producing a welded seam consisting of a number of overlapping spots. This was first done by means of mechanically operated interruptions but lately grid-controlled rectifiers have brought about improvements in this connection. The grid-controlled discharge vessel acts as an alternating-current switching apparatus and makes it possible to pass or intercept the current in the valves and thus switch the welding transformer in or out of circuit as required. Unlike what happens in the mechanical interrupter, these switching processes in the welding circuit occur with great accuracy, without inertia, without contacts, and at any desired switching frequency. It is said that the high-speed spot-welding process can be exploited to the full only by the application of accurately operating grid control, permitting each spot to be welded within the shortest possible time at such a high current that a dependable weld is obtained under all circumstances. On the other hand, since the welding period is short, unnecessary or harmful heating of the metal is avoided.

The connection diagram of the rectifier-control welding machine is given in Fig. 8. In the rectifier section may be seen the two double-anode grid-controlled glass-bulb rectifiers which

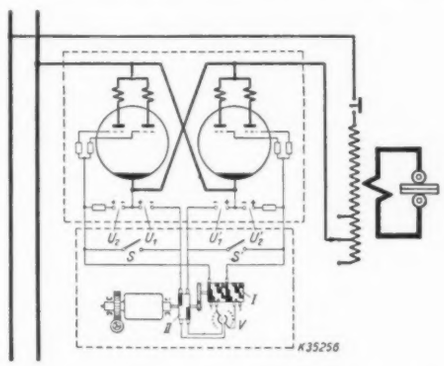


FIG. 8 CONNECTION OF GRID-CONTROL WELDING MACHINE

are connected directly in the circuit of the transformer primary. Multi-anode glass-bulb units are used for reducing the anode load; the anodes of each unit are connected together by dividing coils. The control of the grid is purely direct current. Negative direct current $U_1(U'_1)$ or positive direct current $U_2(U'_2)$ is impressed on the grids, according to the position of the switch $S(S')$ on the switch drums.

In operation, the small controller *I* in the grid circuit fulfils two functions, viz., switches the current in and out at the desired switching frequency and also prescribes the adjustable ratio of "on" and "off" periods. The controller is fitted with short-circuiting contact segments of graduated lengths for this purpose. These groups of segments are arranged in several rows so that the circumference of the controller drum can correspond to one, two, three, etc., welding periods (time during which current flows plus interval). In this way the switching frequency can be altered within the limits demanded in practise without altering the gearing ratio, even when the controller is driven synchronously. A single plain change-over switch *V* is provided for adjusting the two actions of the controller *I*. By equipping the controller drum with stepped segments, infinitely variable regulation is dispensed with. But this has no disadvantage from a practical aspect, for exhaustive welding tests verify that the chief necessity is perfectly accurate and uniform switching, and that a number of different ratios of heating to cooling time is sufficient. The driving of the controller by a synchronous motor has also proved to be successful in many difficult welding processes, where it is necessary to work with very short "on" periods and long intervals.

As an example of a difficult welding job, the welding of stainless steel is mentioned. This steel can be welded by the ordinary methods but generally loses its non-rusting properties during the process, due to the fact that an excessive period of heating leads to recrystallization and the separation of carbide throughout the thickness of the metal. In addition the tarnishing of the surface is a direct cause of rust. It is stated, however, that grid control now enables stainless steel of a considerable thickness to be seam-welded without any surface discoloration. Grid-control welding is also said to be successful with aluminum and aluminum alloys and heavily scaled steel plates. (*A. E. G. Progress*, vol. 1934, no. 2, pp. 30–31, 3 figs., *d*)

The Selection and Replacement of Equipment

(*Continued from page 592*)

additional cut-off saw, costing $300, or by installing a lumber lift, costing $2540, to serve the present cut-off saw. The data for making the replacement study were rather limited, so the figures in Table 3 simply charge the additional saw with the extra labor that would be required if it were purchased, and charge the lumber lift with the additional power that would be required if the lumber lift were installed. Neither is charged with the space occupied as there is no other present use for such space. Fixed charges on the additional saw and the lumber lift are based on a five-year life, with a return of 12 per cent on the average investment during that period. Fixed charges on the present saw are disregarded, as they will be the same in either case. Insurance and taxes are figured at 3 per cent. The values for *A* and *B* will be the same as in Example 2.

The figures in Table 3 indicate that the annual charges will be $928 per year less with the lumber lift than would be the case with the additional cut-off saw.

TABLE 3

Factor	Additional saw	Lumber lift
I	$300	$2540
A	0.072	0.072
B	0.018	0.018
D	0.20	0.20
$A+B+D$	0.29	0.29
Y	$300 \times 0.29 = 87$	$2540 \times 0.29 = 736$
C	50	38
E	...	10
F	...	...
M	...	...
L	1575	...
T	...	...
R	$1712	$784

Electric Welding in Power-Plant Maintenance

(*Continued from page 612*)

becoming loose on the journal, and the weld controlled so as to minimize internal stresses and possible distortion of the shaft. From further discussion it was concluded that these factors could be held within allowable limits, and that it would be possible to make the weld without removing the shaft from the engine.

After considering the two methods it was decided to proceed with repairs by electric welding.

PROCEDURE FOLLOWED IN MAKING REPAIRS

The first step in this procedure was to remove all of the metal within $^3/_4$ in. of the fracture by drilling and chipping.

Fig. 10 shows how the cavity appeared after removing the metal adjacent to the fracture preparatory to welding.

The bearing caps were removed from all main bearings and the entire crankshaft was carefully aligned. In order to secure a comparison of shaft characteristics before and after welding, bridge-gage readings were made of each main journal in four positions 90 deg apart. Web-deflection readings were taken by attaching a dial indicator between each crank web and revolving the shaft. Fig. 11 shows the bridge gage in position preparatory to securing a reading and Fig. 12 shows the dial indicator in position for indicating web deflections.

The shaft was placed in the most convenient position to handle the welding. Electric-welding equipment was moved in position and dial indicators were arranged between all crank webs as illustrated in Fig. 12. A pneumatic chipping hammer with ball-peen tool was placed in convenient reach of the welder. The first bead was laid in at the bottom of the hole starting at the keyway and moving outward 3 in. Succeeding beads were laid in on the side and parallel until the first stratum was in place. This stratum was then peened with the pneumatic hammer in order to relieve local stresses and prevent distortion. An interval of time was then allowed for an even distribution of heat through the surrounding metal.

This process was repeated while a continual check was being made of the bridge-gage and dial-indicator readings in order to detect any shaft distortion which might occur. When the weld was approximately 25 per cent complete, the crank web reached a temperature of 125 F; the dial indicator on web 1 read 0.002 and that on web 2 read 0.001. Bridge-gage readings and dial-indicator readings on webs 3 and 4 showed no variation. The welding was then discontinued and the shaft allowed to gain an even temperature. At this time the dial indicator on web 1 read 0.001 and that on web 2 read 0.0005. Welding was then resumed at the outside end of the hole, using the previously outlined process of peening and allowing time for proper heat distribution.

DISTORTION CHECKED DURING WELDING

As the welding progressed, the dial indicators moved from plus 0.001 on web 1 and 0.0005 on web 2 to zero and then to the minus side, so that at the time necessary to allow the shaft to cool, the indicators on web 1 read —0.001 and that on web 2 read —0.0005. Bridge-gage readings and dial-indicator readings on webs 3 and 4 remained constant.

The weld was completed following the original procedure, with the exception that the point of welding was transferred from one position to the other and the amount of peening varied as required in order best to prevent distortion. At the completion of the weld and after allowing the shaft to regain normal temperature all dial indicators read zero and the bridge-gage readings remained at their original values. The weld was then dressed by chipping and filing.

Fig. 13 shows the completed weld. It will be noticed that the repair can scarcely be distinguished from the original metal.

Bridge-gage readings were then taken of each journal in four positions and web-deflection readings were taken at each crank web. These readings were compared with those taken before repairs were made and were found to be identical.

The bearing caps were replaced and the engine operated under full load for 24 hours, at which time it was shut down for inspection of the weld. As the unit passed through its critical speed, during starting and stopping, the normal amount of vibration was present. An inspection of the weld showed that satisfactory repairs had been made.

Large Tanks Under External Pressure

(*Continued from page 608*)

With the $26^1/_2$-in. vacuum, all flat and high lobes were struck four sharp vibratory blows with a 10-lb sledge-hammer to ascertain what effect such blows might have on the structure as a whole. A thorough inspection afterward showed all welds and seams to be intact. The tank was allowed to remain under vacuum for approximately five days.

COMPARISON OF RESULTS WITH BOILER CODE RULES

Upon the completion of this test the author secured a copy of the "Proposed Rules for the Construction of Unfired Pressure Vessels Subjected to External Pressure,"[3] which is a part of the Code for Unfired Pressure Vessels of the A.S.M.E. Boiler Code Committee. In comparing the results of this test with the rules set forth in this code, the ratio of $L/D = 113/117 = 0.965$, the 113 in. being the greatest length of the two-section tank and the 117 in. being the outside diameter of the tank.

In reading the chart which is Fig. 2 of the section of the Code for Unfired Pressure Vessels referred to,[3] it will be noticed that 15 lb (which is comparable to absolute vacuum) and an L/D ratio of 0.965 gives the t/D ratio approximately 0.0039. This ratio, multiplied by the outside diameter 117, gives a plate thickness of 0.456 in. This has been based, of course, upon the assumption that the two mating flanges of the tank would offer support as a stiffening ring. They are, however, somewhat small when comparing the chart shown on Fig. 6 of the Code,[3] which requires the stiffening rings to have a moment of inertia in the neighborhood of 15, whereas the actual value in this case was 8.

Another deviation from the Code regulation is in the allowable difference in minimum and maximum diameters for the cylindrical vessels. Fig. 4 (of the Code[3]) allows a variation of only the thickness of the wall. The measurements on the transformer tank showed approximately twice the thickness of the wall which is common shop variation for tanks of this kind.

The author believes that the proposed rules[3] are a real contribution to this particular phase of tank construction as they cover thoroughly all phases encountered in the calculation of such a structure. The curves and diagrams are self-explanatory and are easily adapted to any problem of this nature.

[3] See MECHANICAL ENGINEERING, April, 1934, pp. 245–249.

BOOK REVIEWS AND LIBRARY NOTES

Government and Technology

GOVERNMENT AND TECHNOLOGY. By William Beard. The Macmillan Company, New York, 1934. Cloth, 5¼ by 7¾ in., 599 pages, illus. $3.75.

REVIEWED BY ROY V. WRIGHT[1]

IT SEEMS strange, indeed, considering the extent and great variety of engineering projects carried on by governments—municipal, county, state, and Federal—and with all the impacts which technology has on governmental processes and activities, that we should have had to wait so long for a book of this type. Even stranger, that so little attention has been given to this vital problem by engineering educators, many of them associated with colleges maintained largely, if not entirely, at public expense. Possibly the prime reason for such an omission is that with all the concentration on specific technological projects we have failed to appreciate the effect of technology upon our common interests; moreover, we have grown so accustomed to the increasing number and variety of intimate contacts of government upon our lives, individually and collectively, that we fail to recognize their full significance.

William Beard is an instructor in government at the California Institute of Technology. He is a graduate of the Massachusetts Institute of Technology and is the son of Charles A. Beard, historian and student of economics and politics, and of Mary Ritter Beard, writer and suffrage leader. Engineers will recall that Doctor Beard, the father, edited the book, "Toward Civilization," a companion volume to "Whither Mankind," but written by engineers and published at the time of the celebration of the Fiftieth Anniversary of The American Society of Mechanical Engineers in 1930. The background and training of William Beard have prepared him well for the task he has undertaken.

In approaching the problem in the first chapter, "Contacts of Technology With Government," Mr. Beard speaks thus of the obligation of the engineer to society:

"From this statement of facts it appears that the contacts of the engineer with government are numerous, complex, and fundamental; and if he is to rise above the level of the mechanical routineer, he must take account of them. This is the case presented in its narrowest and most practical terms. If, however, the engineer considers his relations with government in all their ramifications, his thought is widened to include the continuing and increasing impacts of technology on government and industrial society with which his fate, in common with that of all citizens, is closely linked. This obligation he can scarcely escape, even by seeking refuge in specialism, by putting on thick blinders. The functions of industrial society and government are so largely technological in character that the engineer will, whatever his personal views, occupy a central position in the future; his science will become more and more indispensable to the conduct of government and the stability of industrial society."

The earlier chapters of the book discuss the broader, fundamental problems involved. The second chapter, for instance, outlines the barriers set up by the political boundaries and jurisdictions in the way of efficient functioning of technological processes. Another chapter considers the problems of popular control in a technological society. The separation of powers of government and the checks established by legislative, executive, and judicial processes are discussed in detail, with illustrations as to how they affect technological activities. The author then proceeds to point out how "technology has given new and significant aspects to the ancient controversy over personal liberty," and closes his treatise with discussions of city and regional planning, and national planning. Here, as elsewhere in the book, are evidences of up-to-dateness, frequent references being made to such things as the National Recovery Act, the Agricultural Adjustment Act, etc. Emergency acts such as these will, of course, expire automatically, but as Mr. Beard sagely observes, "the challenge of the new age to engineers is still open and will long remain open. It is to be hoped that the rising generation of engineers will face that challenge boldly and apply the indispensable instruments of their science—rationality and efficiency—to both government and industry."

While, as designated on the title page, the book is intended for engineering students, it can be read and studied with profit by all engineers; indeed, it should help all of us to understand better how to discharge more effectively our responsibilities as citizens and to elevate our profession to higher standards of public service.

The treatise is made more interesting and valuable because of numerous citations of engineering experiences to illustrate the points which the author wishes to make. The bold-face sideheads for the chapter subdivisions may be characteristic of textbooks, but they do not interfere with the readability of the book and are convenient for ready reference purposes. An excellent bibliography is included. Mr. Beard is to be commended for pioneering so effectively in a field which has too long been neglected by engineers and engineering educators.

[1] Managing Editor, *Railway Mechanical Engineer*, New York, N. Y. Past-President, A.S.M.E.

America's Capacity to Produce

AMERICA'S CAPACITY TO PRODUCE. By Edwin G. Nourse and associates. The Brookings Institution, Washington, D. C., 1934. Cloth, 5¼ × 8 in., 608 pp., illus., $3.50.

REVIEWED BY WALTER RAUTENSTRAUCH[2]

THIS book, say the authors, is "the first volume in a series of four studies dealing with the distribution of wealth and incomes in relation to economic progress." It purposes to answer the question: "Did actual production ever in our most prosperous years utilize our full productive capacity, and if not, how much latent capacity was there which might have been drawn upon for the satisfaction of people's wants through some better method of handling our economic affairs?" Accordingly, the authors posing this question are obligated to determine the "actual production" or total physical production of the national plant; the productive capacities of the several divisions of the national plant as operated by our present "methods of handling our economic affairs;" and to estimate the probable production of the national plant if it had been operated by "some better method of handling our economic affairs."

[2] Professor of Industrial Engineering, Columbia University, New York, N. Y. Mem. A.S.M.E.

The authors state (p. 22), however, that "there are, of course, great possibilities of increase as a result of.....advancing techniques and improved labor efficiency;" and again (p. 23), "we are not attempting to calculate productive performance that might be brought about under ideal conditions." If "ideal conditions" may be interpreted as "some better method of handling our economic affairs," then the last of these objectives is denied. Indeed the book does not attempt an estimate of possible production by the best known methods of scientific management of productive capacity and labor, nor the effects on production of a more workable organization of the national economy.

The subject matter of the book is presented in four main divisions: raw materials, fabrication, services, and an appendix of statistics and methods of evaluation. The time period 1900 to 1930 is reviewed to determine the growth of plant capacity to productive use, and the situation in the years 1925 to 1929 is used as the base of measurement of "latent" capacity maintainable on a permanent basis.

The results of any scientific investigation are determined by the adequacy of the units and methods of measurement employed. In this respect the book under review may be characterized as a process of stepping off the diameter of a circle with the feet and calculating the circumference to the third decimal place. After stating that "many industries keep no records of capacity" (p. 23) and "trade statisticians....advise us that they have found the measurement of capacity impossible to reduce to a generally satisfactory basis" (p. 24), the authors admit that they "have employed methods of estimating which, to many statisticians and economists, will seem daring, if not hazardous" (p. 27); yet they are confident that their "final estimates have been checked.....to an extent that eliminates possibilities of serious error (p. 28)."

It is unfortunate that the technique employed in arriving at such trustworthy results from confessedly meager and inadequate data is not fully revealed for the benefit of the many statisticians and economists who ordinarily refrain from such "hazardous" methods of estimating.

The authors state "in our analysis we have endeavored to arrive at capacity estimates that are attainable under the practical operating conditions which exist. We have, therefore, brought together from public and private sources all available yardsticks of capacity and then enlisted expert advice as to how far to make allowances for such factors as unavoidable shutdowns for repairs and cleaning, for the seasonal character of demand, and for idle plants and obsolete equipment" with the further stipulation that "details of procedure.....will be explained at appropriate points as the discussion proceeds."

The units which seem to be relied upon for determining a point of departure in estimating relative productive capacities in time are the available labor force in the industry and capital investments in equipment corrected for price variation. After manipulating these and other figures a "practical" estimate of capacity is given.

Applying rather vague methods, an attempt is made to determine the "latent" capacity of the nation's agricultural plant. The fertile acreage available is not considered in the estimates, but only the indexes of farm equipment, live stock, and labor force are relied upon. One fails to find the use to which these indexes are put in estimating capacity.

Such statements as "experience as to the elasticity of agricultural production shows that.....output can be expanded very largely without proportionate increase in equipment" (p. 41) and "....any attempt to estimate the amount of nonutilization of labor capacity in agriculture can hardly be more than an individual opinion" (p. 42), together with the first conclusion which refers to the fact that "there are no specific data by which to measure unused capital plant in agriculture" (p. 42) are indicative of the foundations upon which the estimates of agricultural capacity rest. From a scientific standpoint, the whole process of estimating leaves much to be desired.

Coal and coke, copper, petroleum, and cement are the typical industries examined by the same unscientific methods which characterize the agricultural study. More than 100 pages of miscellaneous statistical data and text material are presented to support the conclusion that in 1929 only 70,000 additional workers were needed to "crowd the plants.....to fullest capacity." How the statistical data are employed in reaching this conclusion is not revealed.

The conclusion of this study is that "full plant operation would have required the drawing in of 1,000,000 workers from outside the group regularly identified with manufacturing" (p. 308) and "....our manufacturing industry was occupied at 80 per cent of practical capacity during 1925–1929."

The public-utility and merchandising studies lead the authors to conclude that the excess capacity in electric power plants was relatively small in 1929 and there was no progressive inflation of capacity from 1900 to 1929; that our transportation system with only a moderate increase in equipment and labor could have carried double the tonnage moved in "the recent era of prosperity;" and that there were more than enough persons engaged in merchandising to have handled an increased production of 20 per cent and still release about 3 per cent of the labor force from the trade group.

Among the final conclusions of this study are:

(1) Our productive system as a whole was 80 per cent of capacity in 1929.

(2) If the unused capacity were utilized it would cause "an increase amounting to 19 per cent above what we produced in the late twenties."

(3) "There was no general tendency to pile up capital equipment in continually growing excess above what could be commercially employed."

(4) The nation was not living beyond its means.

If the remaining volumes in this series are based on such inadequate methods of estimating, one wonders what useful purpose they can serve.

The plain and simple fact of the matter is that sufficient data are not available to make a reliable estimate of productive capacity. And when with such unreliable data and grossly empiric processes it is estimated that the excess capacity of 1929 could have given us a 19 (not 20) per cent increase in production, one realizes the impression made by using odd numbers.

The book does not give a convincing answer to the question it raises. Perhaps no better answer can be given when one attempts to accomplish a given investigation within a given time period.

Books Received in the Library

AERODYNAMIC THEORY, a General Review of Progress Under a Grant of the Guggenheim Fund for the Promotion of Aeronautics. Vol. 1. Edited by W. F. Durand. Julius Springer, Berlin, 1934. Cloth, 6 × 10 in., 398 pp., diagrams, charts, 20 rm. This is the first volume of six which are devoted to a general review of progress in aerodynamic theory during the past twenty-five years, intended to provide students and aeronautic designers with an adequate account of background theory. The present volume contains three monographs: Mathematical Aids, by W. F. Durand; Fluid Mechanics, by W. F. Durand and M. M. Munk; and a Historical Sketch, by R. Giacomelli and E. Pistolesi.

The mathematical monograph, about one hundred pages long, treats

briefly various mathematical topics used in the development of aerodynamic theory which are not usually included in the curricula of engineering courses. Fluid mechanics is treated in a relatively extended review, covering two hundred pages, in which developments of special interest to the student of aerodynamics are emphasized. The historical sketch is an admirable account of the development of the subject from antiquity to the present day.

The entire work, in which many leading authorities have collaborated, will be welcomed by every student.

BERECHNUNG UND UNTERSUCHUNG VON KOLBENKOMPRESSOREN NACH NEUEN ENTROPIETAFELN FÜR LUFT UND NH_3-SYNTHESEGAS. By F. Fröhlich. V.D.I. Verlag, Berlin, 1934. Paper, 8 × 12 in., 21 pp., charts, tables, 7 rm. The method of calculating piston compressors by means of entropy diagrams, introduced recently by Ostertag, is extended in the present work to higher pressures up to one thousand atmospheres and more. The clearness and ease of application of the method are illustrated by a number of examples selected from practise, and the thermodynamic principles are explained. Entropy diagrams for air and ammonia are included.

BILDWORT ENGLISCH. Technische Sprachhefte 10, MEASURING PRACTICE. V.D.I. Verlag, Berlin, 1934. Paper, 6 × 8 in., 33 pp., diagrams, 1.50 rm. The latest addition to this series of lessons in English for German-speaking engineers treats of methods and instruments for measuring pressure, time temperature, heat, etc. The method is to provide an English text composed of abstracts from books in English, accompanied by many drawings bearing the English name of each part. An English-German vocabulary is also supplied.

BILDWORT ENGLISCH. Technische Sprachhefte 11, MANAGEMENT. V.D.I. Verlag, Berlin, 1934. Paper, 6 × 8 in., 33 pp., diagrams, charts, tables, 1.50 rm. This pamphlet is one of a series intended to assist German-speaking engineers to read English, especially engineering English. This number is devoted to management. A brief outline of that topic is given in the English language, in which the greatest possible number of technical terms is introduced. The text is illustrated by numerous charts and an adequate English-German vocabulary.

DIESEL HAND BOOK, a practical book of instruction for engineers and students on Modern Diesel Engineering, Land, Marine, Locomotive, Aero, Automotive and Portable Installations. By J. Rosbloom. Diesel Engineering Institute, Jersey City, N. J., 1934. Cloth, 5 × 7 in., 352 pp., illus., diagrams, charts, tables, $5. This handbook presents, largely in the form of questions and answers, advice on the operation and maintenance of Diesel engines. The work is intended for the engine driver of limited education.

DROSSELKLAPPEN ALS GRUNDABLASSVERSCHLÜSSE UNTER BESONDERER BERÜCKSICHTIGUNG DER KAVITATIONSGEFAHR. By O. Jüngling. R. Oldenbourg, Munich and Berlin, 1934. Paper, 8 × 11 in., 51 pp., illus., diagrams, charts, tables, 4.50 rm. This report is concerned with the redesign of the butterfly valve so that cavitation will be avoided and the valve made suitable as a discharge valve for dams. The advantages and disadvantages of the valve, the danger of cavitation and its relation to design are discussed, and improved methods of design are presented. Finally, data and results from a recent installation are presented.

DIE FACHSPRACHE DER SCHLEIFTECHNIK. By A. Danz. Friedr. Vieweg & Sohn Akt.-Ges., Braunschweig, Germany, 1934. Paper, 7 × 10 in., 62 pp., 2.80 rm. This pamphlet, the first publication of the recently established Institute for Grinding and Polishing of the Braunschweig Technical High School, is concerned with the terminology of the industry. The author discusses the concepts included in the terms used by various trade groups and presents a classification of the methods of grinding used in metal working, and makes recommendations looking toward a standard terminology.

FIVE PLACE TABLE OF NATURAL TRIGONOMETRIC FUNCTIONS TO HUNDREDTHS OF A DEGREE. Compiled by Amelia De Lella. John Wiley & Sons, New York, 1934. Paper, 8 × 10 in., tables, $1. These tables give the sines, cosines, tangents, and cotangents for every hundredth of a degree from zero degrees to ninety degrees. They are printed in facsimile typescript, clearly and legibly, upon a page of convenient size. The values correspond to those given by Briggs.

FORSCHUNGSHEFT 366. ZÜNDUNG UND VERBRENNUNG IM MOTOR. By G. Ackermann, G. D. Boerlage, J. J. Broeze, and W. Wentzel. V.D.I. Verlag, Berlin, 1934. Paper, 8 × 12 in., 26 pp., diagrams, charts, tables, 5 rm. Contains reports of three investigations: The combustion diagram in the case of soot formation, by G. Ackermann; ignition and combustion in Diesel engines, by G. D. Boerlage and J. J. Broeze; and the process of ignition and combustion in compressorless Diesel engines, by W. Wentzel.

HEAT. By J. M. Cork. John Wiley & Sons, New York, 1933. Cloth, 6 × 9 in., 279 pp., charts, diagrams, tables, $3. This text aims to provide the advanced student with a survey of the field which includes recent developments as well as the older classical treatment of the subject. The presentation is brief, but complete, and references to original papers enable the student to investigate particular subjects further.

IDENTIFICATION OF THE COMMERCIAL TIMBERS OF THE UNITED STATES. By H. P. Brown and A. J. Panshin. McGraw-Hill Book Co., New York and London, 1934. Cloth, 6 × 9 in., 223 pp., illus., $3. This book aims to supply the factual and scientific information necessary for the accurate identification of our commercial timbers. The first part deals with wood structure, discussing first the gross anatomical characteristics and the non-mechanical physical properties, and then proceeding to the minute anatomy of wood. The second part of the book consists of two keys for identifying woods; one based on features visible with the naked eye and hand lens, the other requiring a compound microscope. The third section describes our commercial woods by species. The work is profusely illustrated with photomicrographs.

IDENTIFICATION OF THE TIMBERS OF TEMPERATE NORTH AMERICA. By S. J. Record. John Wiley & Sons, New York, 1934. Cloth, 6 × 9 in., 196 pp., illus., maps, tables, $3. The first part of this manual is a concise account of the anatomy and certain physical properties of wood, in which the terms and definitions conform to those adopted by the International Association of Wood Anatomists. Part two is a descriptive key for the identification of the woods of North America, accompanied by brief accounts of the specific groups and numerous bibliographic references. The book is intended to replace the author's "Identification of the Economic Woods of the United States."

INDUSTRIAL FURNACES. Vol. 1. By W. Trinks. Third edition. John Wiley & Sons, New York, 1934. Cloth, 6 × 9 in., 456 pp., charts, diagrams, illus., tables, $6. The third edition of this important treatise has been thoroughly revised, about two-thirds of the book having been entirely rewritten. The work is a comprehensive exposition of the principles which underlie furnace operations and the design of furnaces for heating and annealing metals. The capacity, fuel economy, strength, and durability of furnaces, and the movement of gases in them are discussed theoretically and practically.

INDUSTRIELLES RECHNUNGSWESEN. Part 2: Anwendungen; prepared by Ausschuss für industrielles Rechnungswesen, AFIR, beim Verein deutscher Ingenieure; and edited by O. Schulz-Mehrin and F. Zeidler. V.D.I. Verlag, Berlin, 1934. Paper, 6 × 12 in., diagrams, charts, tables, 9.50 rm. A collection of charts and graphs, accompanied by explanatory text, which provide a practical course in factory accounting, supplementing the theoretical treatment of that subject which was published in 1931. The whole work is an unusually clear, comprehensive discussion of the subject. The book is issued under the auspices of the Committee on Factory Accounting of the Society of German Engineers and the Society of German Machine Works.

THE KINETIC THEORY OF GASES. By L. B. Loeb. Second edition. McGraw-Hill Book Co., New York and London, 1934. Cloth, 6 × 9 in., 687 pp., charts, tables, diagrams, $6. The aim of this work is to provide students and investigators with a book presenting the classical and more modern aspects of the kinetic theory in a form suitable for use as a college text-book and handy reference work. The new edition has been thoroughly revised and largely rewritten in the light of developments since the first publication.

DIE KOSTEN DER LICHTBOGENSCHWEISSUNG. By F. von Meier. V.D.I. Verlag, Berlin, 1934. Paper, 6 × 8 in., 32 pp., diagrams, charts, tables, 1.90 rm. This pamphlet reviews the elements that enter into the cost of arc welding and discusses the amount that each contributes to the total cost. Curves are given which enable the welding engineer to determine costs quickly and accurately for all ordinary classes of work.

LOGARITHMS NUMERICAL AND GRAPHICAL for the Easy and Accurate Calculation of Commercial and Technical Problems. By N. R. Corke. Gee & Co., Ltd., London, 1934. Cloth, 8 × 11 in., 79 pp., charts, tables, 8s. 6d. This book, which is adapted to self study, is intended to equip the reader to use logarithms readily in technical and commercial calculations. The four chief practical applications of logarithms, the table, slide rule, logarithmic graph paper, and alignment chart, are explained and their uses for a variety of purposes illustrated. The book

is unusually clear and practical, and calls for little mathematical knowledge.

MANUFACTURE OF SEAMLESS TUBES, FERROUS AND NON-FERROUS. By G. Evans. H. F. & G. Witherby, London, 1934. Cloth, 8 × 10 in., 187 pp., illus., diagrams, charts, tables, 40s. This is a concise, but comprehensive, description of the methods for making seamless tubing by rolling, drawing, extruding, and casting. The various processes and the necessary equipment are described, with numerous drawings of machines. The book is by an experienced maker of tubing and is a welcome addition to the scanty literature on the subject.

MANUAL FOR THE DESIGN OF PIPING FOR FLEXIBILITY BY THE USE OF GRAPHS. By E. A. Wert, S. Smith, and E. T. Cope. Detroit Edison Co., Detroit, 1934. Cloth, 9 × 11 in., 130 pp., diagrams, charts, $2.50. This work presents all the data necessary for the correct proportioning of the ten shapes of pipe structures in common use, in the form of charts and tables which greatly simplify the design of pipe lines for hot fluids. The data cover pipes of all sizes and all practical materials, operating at any possible temperatures and under any practical bending stresses. The charts were prepared by the Detroit Edison Company, and this publication is a revision, with additions, of a paper presented before The American Society of Mechanical Engineers.

MATHEMATICAL TABLES, reprinted from Searles and Ives' Field Engineering with additions. Compiled and arranged by H. C. Ives. Second edition. John Wiley & Sons, New York, 1934. Leather, 4 × 7 in., 160 pp., diagrams, tables, $1.50. A collection of the mathematical tables most frequently wanted is presented in a volume small enough to be carried easily in the pocket. The type is clear and great care has been taken to insure accuracy. The new edition has been enlarged from fourteen to eighteen tables.

MATHEMATICAL TREATISE ON VIBRATIONS IN RAILWAY BRIDGES. By C. E. Inglis. University Press, Cambridge (England); Macmillan Co., New York, 1934. Cloth, 7 × 11 in., 203 pp., diagrams, charts, tables, $7.50. As a member of the Bridge Stress Committee (1923–1928), Professor Inglis devoted himself to the mathematical analysis of the dynamic stresses in bridges. Since then he has continued his work and now offers this study. He has succeeded in determining simple, yet scientific formulas whereby the dynamic effects in railroad bridges may be predicted with sufficient accuracy for practical requirements. A valuable addition to the bridge designer's library.

MECHANICAL ENGINEERING PRACTICE, a Laboratory Reference Text. By C. F. Shoop and G. L. Tuve. Second edition. McGraw-Hill Book Co., New York and London, 1934. Cloth, 6 × 9 in., 477 pp., diagrams, charts, tables, illus., $4. This book aims to provide a thorough reference text on experimental engineering which will also serve as a manual of laboratory practise. Methods of mechanical measurement and instruments therefor, lubricants and friction, heat transfer, the properties of gases and vapors, the measurement of fluid flow, pumps, compressors, steam-power generating units, refrigeration, and internal-combustion engines are discussed.

MECHANICS, a Text-Book for Engineering Students. By F. Gardner. Oxford University Press, London and New York, 1934. Cloth, 5 × 8 in., 256 pp., charts, tables, diagrams, $2.75. Instead of approaching the subject through the law of moments and the polygon of forces, it is here approached through the principle of the ideal machine. Starting with the wheel and axle, the student is led through kinematics, strength of materials and, finally, dynamics. The text is intended to meet the examinations of the professional engineering institutions of Great Britain.

MITTEILUNGEN AUS DEN FORSCHUNGSANSTALTEN. Vol. 3, Parts 3 and 4, July and August, 1934, pp. 51–84, 85–110. V.D.I. Verlag, Berlin. Paper, 8 × 12 in., illus., charts, diagrams, tables. Part 3, 3.80 rm.; part 4, 2.90 rm. These two numbers contain, as their chief contents, the report of an extensive experimental study of the resistance of steel to corrosion fatigue, and of methods of increasing this resistance by adding inhibitors to the corroding liquid. Other articles include one on a new electric railway car, another on the manufacture of an unusually heavy casting, and a third discussing the comparative merits of Strauss and Scherzer lift bridges.

NATIONAL PHYSICAL LABORATORY, The William Froude Laboratory. Abstract of results published on a methodical series of resistance experiments on ship models and their use in design. By G. S. Baker and A. W. Riddle. His Majesty's Stationery Office, London, 1934. Paper, 8 × 11 in., 24 pp., tables, 6s. From 1911 onward, a series of experiments on ship-model resistance at this laboratory, the results of which have been published from time to time. This publication reassembles these data in tables and figures which are arranged in convenient form for use by ship designers. The information covers a methodical variation of the main features of several ocean-going cargo-ship forms and several vessels of the "coaster" type.

NATIONAL PHYSICAL LABORATORY, REPORT FOR THE YEAR 1933. His Majesty's Stationery Office, London, 1934. Paper, 6 × 11 in., 264 pp. illus., diagrams, charts, tables, 13s. (Can be obtained from British Library of Information, New York, N. Y., $3.50.) The report reviews the work done during 1933 by the various departments of the Laboratory. The important investigations in the fields of electricity, engineering, metallurgy, aerodynamics, physics, etc., are described in some detail, and a list of papers published by the staff is included. As a guide to the work done and in progress, the book will be useful to research workers and engineers in many lines.

NEW BACKGROUND OF SCIENCE. By Sir J. Jeans. Macmillan Co., New York, 1933. Cloth, 5 × 8 in., 301 pp., illus., diagrams, charts, $2.50. "The twentieth century," says Sir James, "has already witnessed two great upheavals in physical science. These are associated with the words Relativity and Quanta, and have forced the physicist of today to view nature against a background of ideas which is very different from that of his nineteenth-century predecessor." In his latest work he discusses the discoveries of Einstein, Bohr, Heisenberg, and others, and explains how these have led to a new philosophy. As in previous books, Sir James has kept in mind the general reader, as well as the student of physics, and the book is eminently clear and readable.

PIPE LINE FLOW FACTOR IN THE "HYDRAULIC" FLOW FORMULA $\left(h = f\frac{l}{d}\frac{v^2}{2g}\right)$ and Its Relation to Density and Viscosity. By F. M. Towl. Published by the author at 26 Broadway, New York, 1934. Cloth, 6 × 9 in., 52 pp., diagram, chart, tables, free while supply lasts. This paper is intended to simplify the work of engineers interested in the transportation of fluids through pipe lines. The author discusses the coefficient of flow and its relations to steady flow through cylindrical pipes and to the Reynolds number. A slightly modified form of the flow formula is suggested, from which tables or curves can be constructed that simplify the solution of pipe-line problems. The practical applications of the modified formula are illustrated.

POWER PLANT TESTING, a Manual of Testing Steam Generating Equipment, Engines, Turbines, Pumps, Refrigerating Machinery, Fans, Fuels, Lubricants, etc. By J. A. Moyer. Fourth edition enlarged. McGraw-Hill Book Co., New York and London, 1934. Cloth, 6 × 9 in., 614 pp., illus., diagrams, charts, tables, $5. The aim of this volume is to give in some detail, the generally approved methods of testing engines, turbines, boilers, and power-plant auxiliary machinery, accompanied by descriptions of the apparatus used and the calibrations required for accurate work. This edition has been rewritten and enlarged, particularly with reference to the codes for testing approved by various engineering societies, and again represents up-to-date practise. The book is intended as a laboratory manual for students, and a reference book for the engineer of tests.

LE POMPE CENTRIFUGHE. Calcolo e Costruzione. By G. Zappa. Ulrico Hoepli, Milan, 1932. Paper, 7 × 10 in., 320 pp., diagrams, charts, tables, 45 lira. A comprehensive book on the design of centrifugal pumps, in which the hydraulic principles are discussed thoroughly and their application in design illustrated in detail. The treatment is theoretical and intended for the designer rather than the builder of pumps.

RECOMMENDED ENGINEERING DRAWING PRACTICE. By Institution of Engineers, Science House, Gloucester and Essex Sts., Sydney, N.S.W., Australia, 1934. Cloth, 6 × 10 in., 128 pp., diagrams, charts, tables, 4s. 6d. This volume is nominally a second edition of "Mechanical Drawing Standards," published by the Institution in 1926. The work has, however, been extended to embrace the drawing practise of all the main branches of engineering and has been rewritten and revised. It is offered as a code, intended to promote uniformity of practise throughout the Commonwealth.

DIE SCHWEIZERISCHE MASCHINEN- UND ELEKTROINDUSTRIE. Zum 50-Jährigen Bestehen des Vereins Schweizerischer Maschinen-Industrieller, 1883–1933. Collected by B. Lincke. Orell Füssli Verlag, Zurich, Switzerland, 1934. Cloth, 8 × 12 in., 88 pp., tables, charts, 4.50 Swiss francs. This volume is issued by the Verein Schweizerische Maschinen-Industrieller to commemorate the fiftieth anniversary of its founding. It reviews the changes of tariff, commercial and social policies during the period, and the effects upon the Swiss machine

industry, technical developments, and world markets. The history of the Society is also sketched, with biographies of its officers and accounts of its principal activities.

SCIENTIFIC AND TECHNICAL PAPERS. By K. Suyehiro. Compiled and published by The Suyehiro Memorial Committee, Tokio, 1934. Cloth, 8 × 11 in., 457 pp., illus., diagrams, charts, tables. This handsome memorial to the noted Japanese engineer contains forty-five papers by him, reprinted from various periodicals. Dr. Suyehiro was for many years professor of naval architecture and applied mechanics at Tokio. He was also director of the Earthquake Research Institute. His research work included studies of the structural strength and rolling and vibration of ships, problems in applied mechanics, and investigations of seismological questions, especially those related to the design of earthquake-resistant structures. With but few exceptions these papers are in the English language.

LE TAYLORISME. By H. Le Chatelier. Dunod & Co., Paris, 1934. Paper, 7 × 10 in., 238 pp., illus., paper, 24 fr.; bound, 34 fr. This is a new edition of Le Chatelier's classic work on Taylorism, enlarged by new chapters upon: the rôle of common sense in the organization of work, the study of organization in primary education, the organization of work and the social question, and rationalization and the economic crisis.

Since the first appearance of the book, the economic crisis has affected the civilized world, production has lessened, and works have been idle. Many writers have attributed these events to overproduction resulting from increased mechanization of factories. This view is vigorously combated in the present work.

TECHNISCHE THERMODYNAMIK. (Sammlung Göschen 1084.) By W. Nusselt. Walter de Gruyter & Co., Berlin and Leipzig, 1934. Cloth, 4 × 6 in., 144 pp., diagrams, charts, 1.62 rm. The fundamentals of engineering thermodynamics are presented concisely, yet clearly in this little volume, in which the results of recent research work are presented. Special attention is given to the second law of thermodynamics and the properties of steam.

TEXT BOOK OF APPLIED HYDRAULICS. By H. Addison. John Wiley & Sons, New York, 1934. Cloth, 6 × 9 in., 409 pp., illus., diagrams, charts, tables, $5.50. This textbook contains, in part one, a compact summary of the fundamental principles of hydraulics, and in part two, a longer but equally condensed description of the practical application of these principles to engineering problems, turbines, pumping machinery, power transmission, etc. The book is of college grade, and especial attention has been given to the needs of readers whose work is not directly connected with hydraulics but who need to be familiar with hydraulic practise.

Correspondence

External-Compression Diesel Engines

TO THE EDITOR:

May I refer to the abstract[1] in the August issue on an external-compression Diesel engine by Dr. Siegfried Grantz and Dr. Paul Rieppel from the *Zeitschrift des Vereines deutscher Ingenieure*. The Combustion Utilities Corp., a subsidiary of Henry L. Doherty & Co., of New York, have experimented on an engine of this very type for many years (patents are applied for) and, as far as I know, the difficulties to be overcome on this type of engine are very serious ones.

In so far as I can see there are two points which present great obstacles to an engine of this kind. In the first place, we know that in a Diesel engine combustion of the fuel must have terminated not later than after 10 per cent of the stroke if the engine is to be economical and safe in operation. In the proposed engine, the air supply is forced into the cylinder at the beginning of the expansion stroke, that is, the time when combustion should take place. In the second place, the exhaust-gas preheater for the highly compressed air and the high-pressure, high-temperature piping between the preheater and the engine, and finally the inlet valve itself under these conditions will cause an endless source of trouble. Also the speed at which this valve must be opened and closed is not an easy mechanical problem to solve. A few figures will show the seriousness of the case.

At any rate, the originality and the credit for the pioneer work on this engine should come to the American engineering profession.

H. SCHRECK.[2]

Corning, N. Y.

[1] See MECHANICAL ENGINEERING, August, 1934, pp. 491–493.

Domestic-Stoker Performance

TO THE EDITOR:

A reading of the report on the performance of a domestic stoker[3] by Professors Estep and Saylor emphasizes the fact that there has been a demand for a domestic stoker which would successfully burn high-volatile bituminous coal with a degree of cleanliness, efficiency, and convenience comparable to that of a gaseous-fuel installation. This demand has been so insistent that the manufacture and marketing of such stokers have advanced much more rapidly than engineering information has been collected and published. A search of the technical literature of the last four or five years shows that practically nothing has been published on the performance of small stokers using bituminous coals. A few manufacturers maintain engineering departments and laboratories for their own information, but such information is not available to the public. The bituminous-coal industry does not maintain an organization comparable to the Anthracite Institute Laboratory.

As a result of this lack of accurate information concerning the performance of small stokers, the prospective purchaser is left to the mercy of the salesman whose statements he has no way of checking. He, therefore, has no way of determining before purchase what sort of performance he may expect under different conditions of operation. The salesman often persuades a customer to purchase a stoker which cannot possibly be a success when combined with the other parts of the heating system, and the salesman does this, not because he is dishonest or overoptimistic, but because he has not been fully advised of the possibilities and limitations of his product. One unsatisfactory installation does a great deal of harm to the entire domestic-stoker industry but, unfortunately, the converse is not true that a successful plant proves of value to all of the manufacturers, because failures in mechanical equipment are always better known than successes.

It is believed that much could be accomplished in eliminating failures in small-stoker installations if the major manufacturers would take the public into their confidence and publish whatever technical information they may have obtained. This course may give aid and comfort to the competitor, but it will also enable the prospective purchaser to make a wise selection, and the manufacturer who thoroughly understands his equipment and has developed it by making use of sound engineering principles will have little to fear from his competitor who has just something to sell.

WILLIAM G. CHRISTY.[4]

Jersey City, N. J.

[2] Mechanical Engineer, Ingersoll-Rand Co. Mem. A.S.M.E.

[3] See "Domestic-Stoker Performance," by Thomas G. Estep and David C. Saylor, MECHANICAL ENGINEERING, September, 1934, pp. 547–549.

[4] Smoke-Abatement Engineer, Department of Smoke Regulation, Board of Health and Vital Statistics of Hudson County, New Jersey. Mem. A.S.M.E.

WHAT'S GOING ON

Annual Meeting Papers to Be Published in Advance

THIRTY-FOUR technical sessions are planned for the 55th Annual Meeting of The American Society of Mechanical Engineers to be held in New York City, December 3 to 7, 1934. Because last year's plan of confining these sessions to three days was so successful, it will be used again this year.

The Applied Mechanics Division is sponsoring four sessions devoted to vibration, materials, stress analysis, and bearing analysis. It will also cooperate in the session on aeronautics at which aerodynamics will be the general subject. The Machine Shop Practice Division is also planning four sessions, one on machine design, and research sessions on metal cutting, broaching, and welding.

The Railroad Division will have two sessions, one on locomotive design and the other on brakes and car design. The Iron and Steel Division will also have two sessions, one of which will be held jointly with the Lubrication Engineering Committee on plant lubrication and rolling mills. Included in this session will be a report of the A.S.M.E. special committee on wire rope research. Of particular interest will be the session prepared by the Textile Division on cost reduction in textile manufacturing. The Process Division, besides having two heat-transfer sessions, is now scheduling a third session on processing problems in the sugar industry. The Boiler Feedwater Studies Committee, in its two sessions, is to include a summary of published material on embrittlement and progress in research.

The Oil and Gas Power Division is planning to discuss large motorships and Diesel maintenance. Three sessions are being scheduled by the Management Division, one of which will be on budgeting, covering theory and application; a second on suggestion systems, with an interesting discussion of their application; and a third on quality control.

A symposium on domestic heating will be the topic of one of the two sessions of the Fuel Division, while sessions on industrial and central-station power are on the program for the Power Division.

Papers will be presented on education and training in the industries; and a symposium on the engineering aspects of the prevention of occupational disease disability will be presented by the A.S.M.E. Safety Committee. Under the auspices of the Power Test Code Committee papers will be presented by the subcommittee on fan design, and four other research sessions will cover steam research, mechanical springs, boiler feedwater, and fluid meters.

This year for the first time a number of the papers to be presented will be published in the two issues of Transactions of the Society which will be in the mails well in advance of the Annual Meeting. In the October issue the following papers will appear:

"A Mathematical Solution of the Rotor-Balancing Problem," by Jacob Bromberg.

"Effect of Skewing and Pole Spacing on Magnetic Noise in Electrical Machinery," by S. J. Mikina.

"Effects of Side Leakage in 120-Degree Centrally Supported Journal Bearings," by S. J. Needs.

"Exact Construction of the $(\sigma_1 + \sigma_2)$-Network From Photoelastic Observations," by H. P. Neuber.

"New Method of Calculating Longitudinal Shear in Checked Wooden Beams," by J. A. Newlin, G. E. Heck, and H. W. March.

"Dynamic Balancing of Rotating Machinery in the Field," by E. L. Thearle.

"High-Pressure-Steam and Binary Cycles as a Means of Improving Power-Station Efficiency," by G. A. Gaffert.

"The Relative Grindability of Coal," by H. J. Sloman and A. C. Barnhart.

"Pulsating Air Flow," by N. P. Bailey.

"The V-Notch Weir for Hot Water," by Ed S. Smith, Jr.

"Calibration of Rounded-Approach Orifices," by J. F. Downie Smith.

"Influence of Bends or Obstructions at the Fan Discharge Outlet on the Performance of Centrifugal Fans," by L. S. Marks, J. H. Raub, and H. R. Pratt.

Local Sections' Conferences an Opportunity for Members to Present Ideas

THE success which attended the new plan of having the Local Sections Delegates meet by groups instead of in a general conference in New York at the time of the Annual Meeting, has encouraged the Council and the Committee on Local Sections to repeat the plan this year. This has been done chiefly, of course, because of economic pressure. However, instead of subsidizing part of the traveling expenses of only one representative from each group to the Annual Meeting, it will be possible to care for a portion of the expenses of two representatives from each group, thereby bringing about a conference during the meeting of fourteen representatives of the sections throughout the country.

The general scheme of operation will be for each section to send an official delegate to represent it at the conference scheduled for its group. At these conferences the general trend of the Society's affairs will be discussed and there will be an opportunity for sections through their delegates to make recommendations on new projects as well as current activities. The official representatives of each group will select two of their own number to represent that group at the Annual Meeting to report the gist of the discussion and to present such resolutions as may be decided upon at these individual conferences. The delegates meeting in New York will join with the Council and members of standing committees in discussing the general program of the Society for the ensuing year.

Members of any section having ideas which they wish to have presented should forward them without delay to the chairman or secretary of their particular section. The following is the list of places where various groups will meet with the name and address of the individual in that locality who can give further information regarding the meetings.

Group I: Worcester, Mass., October 20 and 21, H. C. Kendall, chairman, 32 Buckingham Street, Worcester.

Group II: New York, N. Y., 29 West 39th Street, October 24 and 25. J. N. Landis, chairman, Brooklyn Edison Co., 380 Pearl Street, Brooklyn, N. Y.

Group III: Ithaca, New York, October 27 and 28. Dean Dexter S. Kimball, chairman, Cornell University, Ithaca, N. Y.

Group IV: Birmingham, Ala., October 20 and 21. J. A. Sirnit, chairman, Alabama Power Company, Birmingham, Ala.

Group V: Columbus, Ohio, October 19 and 20, H. M. Bush, chairman, 299 South Front Street, Columbus, Ohio.

Group VI: Davenport, Iowa, October 20 and 21, Ralph M. Barnes, chairman, 107 Engineering Building, University of Iowa, Iowa City, Iowa.

Group VII: San Francisco, Calif., Oct. 13 and 14, Prof. H. B. Langille, chairman, University of California, Berkeley, Calif.

A.S.M.E. Printing Industries Conference at Philadelphia, October 8 and 9

THE Fifth Conference of Technical Experts in the Printing Industry will be held on October 8 and 9 in the Benjamin Franklin Hotel, Philadelphia, under the auspices of the Printing Industries Division of The American Society of Mechanical Engineers and the Philadelphia Local Section. The meeting will open Monday morning with a visit to the plant of the Curtis Publishing Company, which will be followed by a luncheon meeting and afternoon and evening sessions. A special Benjamin Franklin Dinner has been planned for Monday evening, at which Robert Duane, a great-grandson of Benjamin Franklin, will discuss the life of this illustrious printer. On Tuesday a short session will be held in the morning in the hotel and will be followed by an inspection trip and a buffet luncheon at the Lanston Machine Company. The final session of the meeting will be held at the Franklin Institute, Tuesday afternoon, and will include the or-

ganization meeting of the American Institute for Printing Research and also an inspection trip through the Franklin museum.

The program of the meeting follows:

Monday, October 8

9:00 a.m. Registration, Mezzanine Floor

10:00 a.m. Inspection Trip

Through the plant of The Curtis Publishing Company, producers of *The Ladies Home Journal*, *The Saturday Evening Post*, and *The Country Gentleman*. Group leaves from the hotel ballroom.

1:00 p.m. ***Luncheon, Ballroom.*** ($1.25)

Presiding Officer: Walter D. Fuller, first vice-president, The Curtis Publishing Company.

Opening remarks, E. Epstean, past-president, New York Photoengravers Board of Trade.

The Photomechanics of Color Photography, by Harry A. Groesbeck, Country Life-American Home Corporation.

Discussion by Harold Fowler, Bassani Processes, Inc., and M. F. Agha, The Conde Nast Publications.

3:00 p.m. ***Afternoon Session, Ballroom***

Presiding Officer: Matthew D. Maull, Paterson & White.

Opening of the Fifth Conference by John Clyde Oswald, Chairman, Printing Industries Division, A.S.M.E.

Synthetic Resins as a Process Roller Material, by A. L. Freedlander, the Dayton Rubber Manufacturing Company.

Discussion by W. S. Robinson, The McCall Publishing Company, and E. R. Bridgewater, Rubber Chemicals Division, The E. I. du Pont de Nemours & Co.

Rubber Plates for Letterpress Printing, by Messrs. J. Homer Winkler and Ralph Schwarz, Ace Electrotype Company.

Observations on the Technology of Rubber-Plate Manufacture, by W. J. Ruscoe, The B. F. Goodrich Company.

Discussion by H. W. Haydock, The Royal Electrotype Company.

6:15 p.m. ***Franklin Dinner (informal), Franklin Room,*** ($2.00)

Presiding Officer: Prof. G. E. Crofoot, chairman Philadelphia Local Section, A.S.M.E.

8:30 p.m. ***Evening Session, Ballroom***

Presiding Officer: V. Winfield Challenger, N. W. Ayer & Sons.

Recent Developments in Offset Printing, by Burt D. Stevens, The Miehle Printing Press & Manufacturing Company.

Photomechanical Reproduction of Offset Plates, by W. C. Huebner, The Huebner Laboratories.

Discussion by H. A. Bernhart, Latham Litho & Printing Company, and Randolph T. Ode, The Providence Lithograph Company.

Tuesday, October 9

9:30 a.m. ***Morning Session, Ballroom***

Presiding Officer: H. C. Cole, Acme Gear Company.

Type Design, by Sol Hess, Lanston Monotype Company.

Discussion by Wilfred Bancroft.

10:30 a.m.

Inspection trip through the Lanston Monotype plant and buffet luncheon there at 12 o'clock noon. (Bus fare and ticket, 50 cents.)

1:30 p.m. ***Afternoon Session, Franklin Institute***

(Planetarium entrance, 20th and Winters Sts.)

Presiding Officer: John Clyde Oswald, Chairman, Printing Industries Division, A.S.M.E.

A Comparison of the Reproductive Quality of Aquatone and Other Printing Processes, by Maurice N. Weyl, Edward Stern Company.

Discussion by William C. Huebner, The Huebner Laboratories.

New Development in Color Rotogravure Printing by G. A. Fries, *The News*, New York, N. Y.

Discussion by M. Raoul Pelletier, Gravure Foundation of America, and by F. Weihselbaum, manager, Neo-Gravure Printing Company (The Cuneo Press).

The Printing of Metal Paper, by R. E. Hunt, Reynolds Metal Company.

Discussion by V. Winfield Challenger, N. W. Ayer & Sons.

4:30 p.m. ***Printing Research Institute***

Introduction: What England, Germany, Japan, and France have Accomplished, by Edward Pierce Hulse, Secretary, Printing Industries Division, A.S.M.E.

Address: Organizing the Institute, by Arthur C. Jewett, former director, College of Industries, Carnegie Institute of Technology, Pittsburgh, Pa.; Chairman of Research and Survey Committee, Printing Industries Division, A.S.M.E.

5:20 p.m.

Visit to the printing exhibits of the Franklin Institute (conducted by special guides), 25 cents per person.

Exhibits of machinery and processes covered by the program will be placed in the foyer of the hotel ballroom, these to be approved by the Program Committee.

Wood Industries Division to Have Sessions Both in Philadelphia and Camden

THE National Wood Industries Meeting, under the joint auspices of the Wood Industries Division and the Philadelphia Local Section of the A.S.M.E., will be held this year on October 23 and 24 with sessions in Camden, N. J., at the Hotel Walt Whitman, and at Philadelphia, Pa., at the Philadelphia Convention Hall, during the International Foundrymen's Exposition.

The meeting will open in Camden with an inspection trip through the plant of the Radio Corporation of America, of unusual interest because of the efficient handling of and production methods of radio cabinets. This was formerly the plant of the Victor Talking Machine Co., and it is the first time it has been open for inspection.

An equipment session is to be held on Tuesday afternoon, part of which will be devoted to the discussion of progress in woodworking industries. It is planned in this informal discussion to cover a number of interesting, new processes. On Tuesday evening there will be a management session on economic lot sizes and low-cost housing and the showing of a film on termites.

An inspection trip is scheduled for Wednesday morning to the Camden Vocational School and the Saw Plant of Henry Disston & Sons, while the afternoon will be devoted to a joint session with the American Foundrymen's Association to discuss the subject of wood patterns.

The detailed program follows:

Tuesday, October 23

8:30 a.m. Registration—Mezzanine Floor.

9:30 a.m. Inspection trip through Radio Corporation Plant.

2:00 p.m. ***Equipment Session***

The Economics of Replacement of Manufacturing Equipment in Woodworking Industry, by Paul T. Norton, Jr., Virginia Polytechnic Institute.

Discussion to be opened by Chester L. Babcock, Babcock Machinery Company, with examples of rearrangement and replacement of woodworking equipment.

Economic Loading of Exhaust Fans, by R. H. McCarthy, Western Electric Company.

Progress in Woodworking—a group of short discussions on the latest developments in machinery, processes, products, and economic conditions.

8 p.m. ***Evening Session***

Economic Lot Sizes in the Manufacture of Wood Products, by Paul T. Norton, Jr., Virginia Polytechnic Institute.

Discussion to be opened by R. H. McCarthy and G. E. French, Western Electric Co.

Low-Cost Housing, by R. F. Tucker, Massachusetts Institute of Technology.

Termites, by H. B. Carpenter. Includes the showing of a very interesting film.

Wednesday, October 24

9:30 a.m. Buses leave hotel for Camden Vocational School and Saw Plant of Henry Disston & Sons.

2:00 p.m. Joint session at Philadelphia Convention Hall with the American Foundrymen's Association.

Symposium on Wood Patterns.

A.S.M.E. Transactions for September, 1934

THE September issue of the Transactions of the A.S.M.E. contains the following papers:

The Burlington Zephyr (RR-56-3), by E. C. Anderson

The Design of Light-Weight Trains (RR-56-4), by R. Eksergian

Union Pacific High-Speed, Light-Weight, Streamlined Trains (RR-56-5), by A. H. Fetters

The International Congress of Applied Mechanics Meets in England

THE meetings of the International Congress of Applied Mechanics have been important quadrennial events. This can be said particularly of the recent Fourth International Congress which was held in Cambridge, England, from July 3 to 9 of this year. This meeting, in the opinion of the members, was in general as satisfactory as the previous three held in Zurich (1922), Delft (1926), and Stockholm (1930). The perfect organization of the Congress in Cambridge left a profound impression upon the members and delegates who enjoyed a week as pleasant as it was profitable.

The number of members of the Congress exceeded three hundred, and twenty-seven countries were represented. The dormitories of Pembroke College were open to the single members of the Congress and more than ninety men were conveniently lodged there. The dining hall of the College provided meals for this group. The rest of the attending members were located in the hotels in Cambridge, in the vicinity of the Engineering Laboratory, where the Congress actually was meeting. Mail, banking, and other services were all organized for the convenience of the members who freely expressed their satisfaction to the responsible organizing secretary, A. H. Chapman, of the Engineering Laboratory, Cambridge. The weather was dry and warm, rather unusual for Cambridge, and this circumstance helped appreciably to keep the members in high spirits.

MORE THAN 130 PAPERS PRESENTED

Seven general lectures and more than 130 papers were presented before the Congress. A number of authors from the United States could not attend so that members from this country presented several papers each, as arranged by the Applied Mechanics Division of The American Society of Mechanical Engineers.

The greatest number of the communications, approximately 40 per cent, dealt with various phases of fluid mechanics. The mathematical and experimental study of turbulence, cavitation phenomena, resistance of surface craft, and sedimentation were among the topics covered. There was considerable discussion on the physical explanation of the erosion of propeller blades and container walls caused by cavitation. Attention was given to the importance of applying the principles of fluid mechanics to meteorology.

Various questions relating to the mechanics of structures were dealt with in a number of papers. Stress distribution in and failure of shells, stresses in suspension bridges, stress distribution in a beam under impact, rotating disks, and the stability of structures were among the topics discussed. The photoelastic method and other approximate methods of analysis were dealt with. Several papers were written on the subject of earth pressure.

In the field of dynamics there were several papers on vibration topics, such as the torsional oscillation in electrical machinery and in internal-combustion engines, the vibration of beams, the dynamic loading of systems, and the dynamics of gear-connected low-pressure exhaust turbines. Certain authors reported on the dynamics of trains, both from the viewpoint of the tractive effect and of impact forces on the rail.

The physical nature of structural materials was discussed in various phases by other authors. Fatigue testing and the interpretation of fatigue fractures, notched-bar tests, and the development of surface cracks were among the topics discussed. Further studies in the mechanism of yielding and of tensile and shearing fracture were reported.

A few reports were presented on the mechanism of heat transfer, the properties of vapor, the thermodynamic limits of brake horsepower at altitude. General papers were given on auxiliary methods of applied mechanics, such as approximate solution of equations, high-speed pressure indicators, and graphical and numerical integration.

SEVEN GENERAL LECTURES DELIVERED

Seven general lectures were delivered before the congress. Dr. V. Bush, of the Massachusetts Institute of Technology, talked on "Recent Progress in Analyzing Machines." He pointed out the importance of computing machines which could save the labor of a research man to the same extent that the calculating machines at present save that of business people and statisticians. He went on further to classify the existing devices and described the mechanical integrator of the Massachusetts Institute of Technology for solving differential equations and the photoelectric device in development now as a first step toward a machine for solving integral equations. The lecture by J. P. Den Hartog, of the Harvard Engineering School, on "The Vibration Problem in Engineering," presented the latest developments in the so-called self-induced vibrations and cited a number of instances of these vibrations taking place in structures. Models and analogies of the structures were presented and produced quite an impression upon the audience. Th. von Kármán, of the California Institute of Technology, talked on the general topic of turbulence. He gave a review of the turbulence question today. He showed the similarity of the velocity distribution with the equation of heat transfer and sedimentation by diffusion. He indicated the possible further developments of the theories of Prandtl and Taylor which have recently received much attention in the United States from chemical engineers. He expressed the hope that meteorologists will present their data and make observations in a way to enable the application of turbulence theory to their analysis. Prof. A. Caquot, of Paris, discussed the "Determination of the Elastic Range in Isotropic Materials." He gave a description and interpretation of the experiments made under his supervision on

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steel specimens in order to arrive at values of the true elasticity as compared with the apparent elasticity of the material. E. Schmidt, of the Technische Hochschule, Danzig-Laufuhr, talked on heat transfer. He discussed particularly the heat transfer from a hot body to surrounding air. The distribution of temperature and velocity around a hot vertical plate was shown. He described the experimental investigation of the phenomenon by means of quartz anemometers which can measure air velocities of 1 mm per sec., and of an optical apparatus based on refraction of parallel rays by the warm air surrounding the hot body. The lecture by G. I. Taylor, of Cambridge University, England, was entitled "The Strength of Crystals of Pure Metals and of Rock Salt." He presented an explanation of the plasticity of metals and of crystals in general by a possible dislocation of atoms in the lattice of the crystal due to stress. Analyzing a hypothetical rearrangement of the lattice under stress, he arrived at parabolic stress-strain relations which are substantiated by experimental evidence.

The general lectures and abstracts of all communications will be published in a volume of the proceedings of the Fourth Congress of Applied Mechanics. Unfortunately, because of a lack of adequate funds, all the papers cannot be published in full or even that part of them in which original, important, or unpublished work is reported.

The papers were given in four simultaneous sessions. The secretaries of the British Organizing Committee, Messrs. W. S. Farren, of the Engineering Laboratory, Cambridge, England, and G. I. Taylor must be credited with the careful planning of the meetings.

PRESENTATION OF PAPER BY MEANS OF TALKING MOVIES

An interesting innovation in presenting research work was introduced by two Japanese authors, S. Watanabe and M. Kuroda, of the Institute of Tokio, Japan. Both had had their papers recorded on talking movie films. One film was made with the author actually talking to the microphone while the other was made by a professional reader. Comments from the audience indicated that seeing the lecturer seemed to be more effective and that it was important to hold diagrams on the screen for a few seconds so that they could be absorbed by the listeners.

OTHER FUNCTIONS

The City of Cambridge and the university entertained the members of the congress at various functions. A reception and informal dance were held by the Mayor of Cambridge and the Mayoress at the Guildhall. A conversazione by invitation of Prof. C. E. Inglis was held at the laboratories of the Engineering Department, where demonstrations and exhibits of apparatus were presented to the members of the congress. Other social events included a garden party at the Christ's College, with a concert by the choir of the College, a reception by the Master of St. John's College, the congress dinner in the Hall of Trinity College, and an informal concert at King's College.

The program for the ladies was carefully planned, including visits to various works and cathedrals, as well as to museums and colleges in Cambridge.

NEXT CONGRESS TO BE IN UNITED STATES

The standing committee of the International Congress of Applied Mechanics decided to hold the Fifth Congress in 1938 in the United States in accordance with the invitation of the Applied Mechanics Division of the A.S.M.E. The congress will probably be held the second week of September at Massachusetts Institute of Technology and Harvard under their auspices with some special features arranged at New York City and Columbia University. It is expected that several engineering and scientific societies in this country will cooperate in the 1938 congress.

The foregoing report was prepared by Geo. B. Karelitz, Columbia University.—EDITOR.

Federated Management Societies Formed

THE formation of Federated Management Societies, the joint operating organization of the Taylor Society and the Society of Industrial Engineers, was announced on August 10, as the result of the work of a joint committee of both societies which had studied the situation for a year and a half.

It is expected that the Federation will effect economies which will make possible the rendering of more and better service to the members of both societies. A bulletin will be published regularly and a joint convention in New York in December is contemplated.

Present members of the Society of Industrial Engineers and the Taylor Society will continue to be members of their respective societies, as well as of Federated Management Societies, and will continue to pay dues to the constituent society of which they are respectively members. New members may elect membership in either one of the constituent societies.

Foundrymen's Association Meets in Philadelphia, October 22–26

AS ANNOUNCED in the September issue of MECHANICAL ENGINEERING the Fifth International Foundry Congress and 38th Annual American Foundrymen's Association Convention will be held in the new Convention Hall in Philadelphia, Pa., October 22 to 26. The A.S.M.E. Wood Industries Division, holding its National Meeting on October 23 and 24, will participate in a joint session with the A.F.A.

Among the highlights on the program of the Foundry Congress are the foreign-exchange papers. The Institute of British Foundrymen sends a paper on steel casting by one of its most distinguished members, Dr. W. H.

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Hatfield, of the Brown-Firth Research Laboratory, Sheffield, England. The paper presents a clear picture of modern steel-foundry practise in England. Dr. Hatfield emphasizes the need for cooperation between the designer and the foundryman, illustrating his point with examples of difficult castings.

The Czechoslovakian Exchange paper is entitled "Some Aspects of the Physical Chemistry of Steel Making." Both of the authors, Dr. E. Valenta and Dr. P. Herasymenko, are with the Research Institute of the Skoda Works, Ltd., at Pilsen, Czechoslovakia. They have done a great deal of work on the equilibrium constants of the reactions taking place du ing steel melting. From their investigations, they have developed equations which allow the calculation of the amount of different constituents present, and tables show the close agreement between their calculated and the observed values.

This Month's Authors

Walter Rautenstrauch, who writes on the economics of purchasing, is professor of industrial engineering at Columbia University, New York. He is a frequent contributor to MECHANICAL ENGINEERING, a forceful lecturer on economic and industrial topics, and a pioneer in the use of the so-called break-even chart. At present he is a member of the Finance Committee of the A.S.M.E.

Paul T. Norton, Jr., whose paper on the selection and replacement of equipment is to be presented at the forthcoming meeting of the A.S.M.E. Wood Industries Division, is professor of industrial engineering at Virginia Polytechnic Institute, Blacksburg, Va. Following graduation from the University of Wisconsin he had 16 years of industrial experience, the last three of which were as vice-president of the Case Crane & Kilbourne Jacobs Co., Columbus, Ohio. His teaching experience began at the University of Wisconsin in 1926, and his present connection was formed in 1929.

Eugene L. Grant, formerly professor of industrial engineering at Montana State College, is now associate-professor of civil engineering at Stanford University, giving courses in engineering economics, accounting and statistics for engineering students, and engineering valuation. His article in this issue on "Increment Costs and Sunk Costs" was adapted from a lecture on that subject given at the economics session of the S.P.E.E.'s Summer School for Engineering Teachers held at Stevens Institute in July, 1932, and from a paper "Certain Deficiencies in the Theory and Practise of Cost Estimating" presented at the June, 1934, meeting of the Econometric Society. His professional experience has included work for irrigation enterprises, public water supplies, gas and electric utilities, and railways.

Phillip A. Kinzie, who writes this month on the needle valves and emergency gates for the Boulder power plant, is a native of Denver. He was chief engineer of the Leyner Tractor and Manufacturing Company, of Denver, Colo., when he left, in 1920, to enter the Bureau of Reclamation. At present he is senior engineer in charge of the design of gates and valves in the mechanical-engineering section of the Bureau.

William J. Hart, whose paper on welded tanks subjected to external pressure is the result of his experience in transformer-case design for the Westinghouse Electric & Manufacturing Co., is a specialist in machine design and metallurgy. His duties have included standardizing, cheapening, and improving the design of large power transformers, such as covers, tanks, frames, and bases.

Ernest Joseph King, who contributes this month a report on progress in naval aviation, is a rear admiral in the U. S. Navy and chief of the Bureau of Aeronautics, Navy Department since May, 1933. He entered naval aviation in 1926, when he was in command of U. S. S. *Wright* and seaplane squadrons. From that time to date he has qualified as naval aviator, 1927; commanded aircraft squadrons, scouting fleet, 1928; assistant chief, Bureau of Aeronautics, 1928–1929; in command, Naval Air Station, Hampton Roads, Va., 1929–1930; in command, U. S. S. *Lexington*, airplane carrier, 1930–1932.

J. W. Keck, whose paper on electric welding in power-plant maintenance was enthusiastically received at the meeting of the Florida Section, A.S.M.E., last December, is division plant superintendent of the Florida Power and Light Company, Dania, Florida.

Candidates for Membership in the A.S.M.E.

THE application of each of the candidates listed below is to be voted on after October 25, 1934, provided no objection thereto is made before that date, and provided satisfactory replies have been received from the required number of references. Any member having comments or objections should write to the secretary of the A.S.M.E. at once.

NEW APPLICATIONS

BIDNICK, JOHN S., Kansas City, Kans.
CALIFRO, ERNEST, Oakland, Calif.
CLISHAM, F. R., San Francisco, Calif.
GIEGENGACK, A. E., Washington, D. C.
GILLIES, JOHN H., Drexel Hill, Pa.
HARE, ROSS, Niagara Falls, N. Y.
HAZARD, CHARLES SPRAGUE, Long Island City, N. Y. (Rt & T)
HODGES, MILTON E., Waterbury, Conn.
HOLTZ, JOHN C., Baltimore, Md.
JACOBSON, E. W., Pittsburgh, Pa.
JURGENSEN, CHARLES A., Trenton, N. J.
MARK-WARDLAW, COMMDR. ALEXANDER L. P., Washington, D. C.
MASINO, FRANK DONALD, Brooklyn, N. Y.
MYERS, MAURICE EARL, Antioch, Calif.
NARDONE, ROMEO M., East Orange, N. J.
NICHOLS, PAUL L., Reno, Nevada
RIVOIRA, EDILIO J., Dorchester, Mass.
ROSEN, JOSEPH, Union City, N. J.
ROUSE, RUSSELL F., Fort Collins, Colo.
WALLACE, WILFRED N., Augusta, Kans.
WERAPERMALL, DENZIL N., Grand Pass, Colombo, Ceylon
WINSPEAR, RALPH S., Hartford, Conn.

CHANGE OF GRADING

Transfers from Associate-Member

LEE, CHUN C., Canton, China
SLATER, FREDERICK, Vancouver, B. C.

Transfers from Junior

BEITLER, SAMUEL R., Columbus, Ohio
BENEDICT, WALTER E., Trenton, N. J.
BROWNE, ANDREW T., Philadelphia, Pa.
BURACK, WILLIAM D., Livingston, N. J.
CASIRAGHI, GIOVANNI P., Troy, Ohio
EILERTSEN, THOR, Long Island City, N. Y.
ESKELUND, A. K., Copenhagen, Denmark
GAYNOR, HUGH F., New York, N. Y.
GURNEY, WILLIAM B., Baton Rouge, La.
HOPE, ERIC S., Saylesville, R. I.
KAVENY, THOMAS, JR., Pittsburgh, Pa.
LUCARELLI, BENJAMIN J., Jersey City, N. J.
MALLORY, BURTON C., Lynn, Mass.
MEYER, ROBERT MAXWELL, Tenafly, N. J.
MARINO, S. F., Plainville, Conn.
MAYER, FRED, Seattle, Wash.
MOHN, PAUL E., Urbana, Ill.
PALMER, ALBERT, Worcester, Mass.
SMITH, WARREN H., Detroit, Mich.
SULLIVAN, J. F., JR., Chicago, Ill.
WALKAMA, TOIVO EDWARD, Jersey City, N. J.
YOUNG, H. RUSSELL, Philadelphia, Pa.

Recent Deaths

BROOKS, HENRY K., August 12, 1934
COFFIN, WILLIAM J., June 14, 1934
CRAMER, A. N., June 21, 1934
CRARY, JAMES H., July 21, 1934
LAWRENCE, RUSSELL E., June 15, 1934
RYAN, HARRIS J., July 3, 1934

Pictures

GERALD YOUNG, who, not so many years ago, was a member of the A.S.M.E. Student Branch at the University of Iowa, and is now a junior member of the Society, is the photographer of this month's frontispiece. From his camera also came the cover of the February, 1933, issue, a study of smoothly running gears and wheels and of lights and shadows. Pictures of this type add little to our knowledge of machinery and engineering but they provide a needed aesthetic relief and demonstrate that the elements of beauty abound in the familiar environment of the engineer.

In connection with the picture of the carding machine at the Amana mills, Mr. Young writes that the Amana Society, located in Iowa for the past 100 years, has been a cooperative enterprise until two years ago when it reorganized into a corporation. The making of fine woolen goods has provided its people with work for more than half a century.

Another example of the effects that can be obtained by photographing machinery with artistic skill is found on this month's cover. The photographer is Mr. Bancker.

Pointing With Pride

ZENAS R. BLISS, vice-chairman of the A.S.M.E. Providence Section, was navigator of the *Rainbow* during the recent races.